Academy of Denture Prosthetics Meeting, Louisville, Kentucky, April 12 to 17, 1959.

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VOLUME 9 MARCH-APRIL, 1959 NUMBER 2

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COMPLETE DENTURES
REMOVABLE PARTIAL DENTURES
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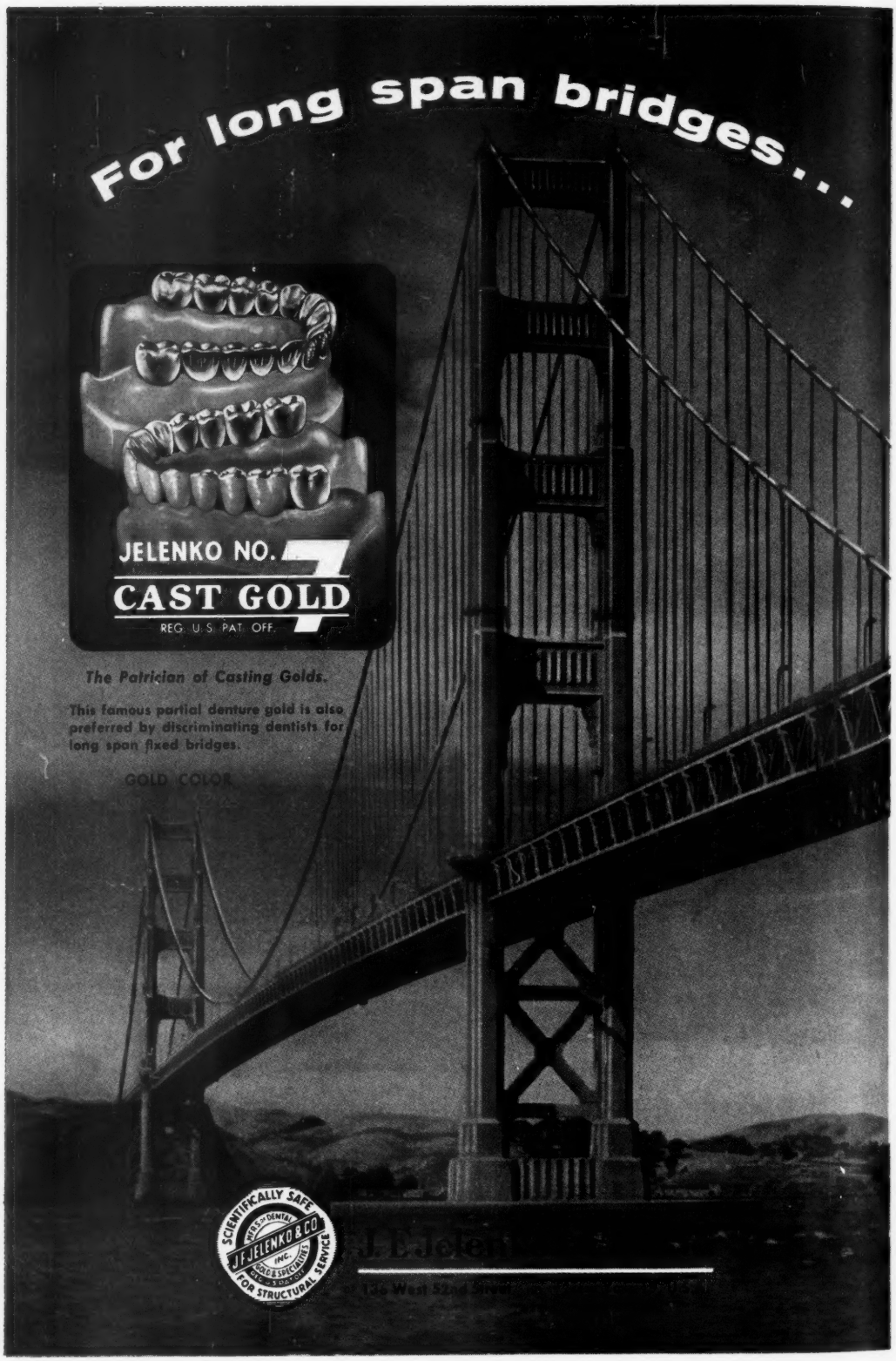
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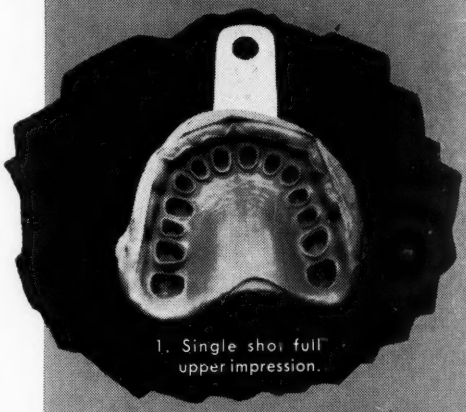

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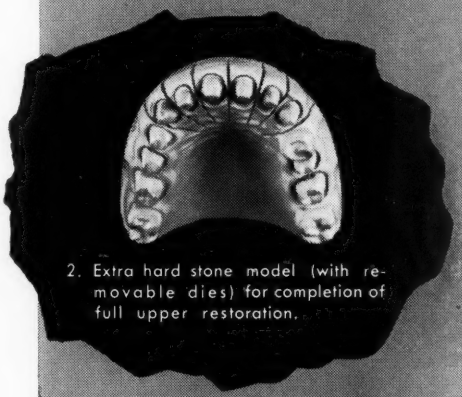

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THROUGH THE EYES OF THE EDITOR

Arthur F. Russell discusses the effect of the accessory muscles of mastication upon the retention of mandibular dentures and describes his technique for applying the principles of reciprocating forces to denture design. The technique provides a means for recording the shape of the denture space when the muscles of the cheeks, lips, and tongue are in function. Thus, these structures are used to help to maintain the denture in position rather than to dislodge it. He gives less consideration to the leverages involved in toothridge relations while he places greater emphasis upon the musculature around the dentures. Both factors must be recognized and coordinated if the maximum success is to be achieved.

Ralph H. Boos discusses centric relation and his concept of the occlusion which should be coordinated with it. He points out the need for harmony between the occlusion and the temporomandibular joints and the musculature of the mandible. He recognizes eccentric habit relations of the jaws and suggests that the occlusal contacts of the teeth be developed in such a way as to provide centric occlusion at the "functional area" as well as at centric relation. This is accomplished by making two registrations. One of these is made at centric relation and the other at an eccentric relation which is habitual for the patient. He suggests techniques for making these registrations. He is in agreement with those who believe that the teeth should contact evenly wherever they may close into contact.

Charles H. Moses discusses the form of human teeth and their arrangement from the anthropologic approach. He recognizes wear of teeth as a physiologic process and criticizes the concept that the original natural forms of teeth should be maintained or restored. He points out various physiologic changes which occur "because of wear" and that the angle of wear conforms to the chewing cycle. This might be a problem similar to that of which came first, the chicken or the egg. He shows the relation between the relative size of the arches and the inclination of the teeth and that the architecture of the bone is related to inclination of the teeth. He points out the very important fact that techniques are based upon concepts and that erroneous concepts must be corrected so errors do not become a part of techniques. The problem is to determine which is the correct concept.

Honorato Villa A. discusses the requirements of articulators for reproducing protrusive movements. He uses some ingenious models to demonstrate his concept of these movements. He sees the inclination and curvature of the condylar guidances and the relation of these paths to the incisal guidances as being most important. In order to keep these relationships constant, he suggests that both the condylar guidance and incisal guidance should be parts of the upper member of the articulator. This is different from most articulators.

Charles E. Stuart discusses the accuracy of jaw relation records as they may be recorded

on an articulator and describes his instruments for making these records and for reproducing them. The recording devices are capable of recording the border movements of the mandible, and the articulator can be made to reproduce these records. The instruments are more effective when the recording devices are attached solidly to natural teeth.

C. N. Skinner describes his classification of partial dentures which is based upon the relationships of the abutment teeth to the supporting residual ridge. The classification seems to be simple enough to be practical and flexible enough to cover all situations.

Thomas D. Gilson describes an interesting precision type of attachment for making the pontic sections of fixed partial dentures removable (by the dentist). The design of the attachment is quite ingenious and the technique for its use is not too difficult. The attachment could be of great value for fixed restorations which are to be supported by teeth that cannot be modified sufficiently to parallel the preparations.

Louis Alexander Cohn discusses the factors that are involved in planning the occlusion in major restorative dentistry. He considers the potential effects of the restorations upon the periodontium, the residual ridges, and the maxillomandibular relations. He emphasizes the importance of a thorough diagnosis and the design of the occluding surfaces. He warns of dangers in incorrectly designed occluding surfaces. He discusses his philosophy and concept of jaw relationships and points out the critical decisions regarding them which must be made for each patient. The techniques he suggests indicate a recognition of the importance of the coordinated treatment of the oral condition of the patient. Even though his concepts and interpretations may be different from those of some others, his approach involves an interpretation of oral physiology and a recognition of the role of the musculature in oral function and upon the success of restorations.

Albert Zola discusses the advantages of using acrylic resin copings for making jaw relation records and describes his technique for making transfer copings. The accuracy with which they are developed must reduce the possibility of errors in the transfer of jaw relationships to the articulator.

E. D. Shooshan discusses the advantages and disadvantages of the various types of facings which are available for fixed partial dentures. He points out a number of situations where stock facings are inadequate and describes a simple technique for making facings from diatoric or pin denture teeth. Facings of this design should fit the requirements for many pontics.

Robert W. Fischer reports his personal observations on the use of an ultra high-speed air turbine handpiece. He finds that he can make better preparations in less time than with instruments rotating at lower speeds, but he points out certain disadvantages which have become apparent to him. He notes that the instrument cannot be used safely for all operations, and it is obvious that extreme care must be exercised in its use if damage to dental pulps is to be avoided.

William H. Gilmore, Richard J. Schnell, and Ralph W. Phillips report their investigations of factors which influence the accuracy of seven silicone impression materials. The testing methods used were similar to those used for testing other elastic impression materials. They point out certain procedures which can lead to inaccuracy of the resultant dies. These procedures should be avoided if these materials are to be used successfully.

G. E. Myers and F. A. Peyton report their studies of the silicone rubber impression materials in which they found some defects as well as some advantages over Thiokol rubber impression materials. It is apparent that these materials need improvement and that further research will overcome their present unfavorable behavior. The most important defect seems to be inconsistency which was found to be caused by several different factors.

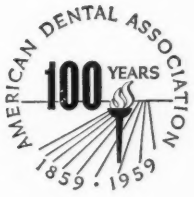
Jean Turnbaugh Hodson reports her investigations of the physical properties of three dental porcelains. The results could serve as guides in the selection of porcelains for specific situations in dentistry. Studies such as this can lead eventually to the elimination of the disadvantages of porcelain restorations.

Howard J. Merkeley reports a preliminary study which indicates that changes do occur in the angles of human mandibles under certain types of stress and that there is a possibility that *some* temporomandibular disturbances may result from these changes. Averages of measurements made on 90 mandibles and 100 roentgen-ray head plates were used as bases for his conclusions. This type of study is

most difficult to make and to interpret because of the absence of the long-term history of each mandible and the judgment involved in determining the angulation. The need for further study of these problems is apparent.

Marsh Robinson describes the surgical elimination of a mandibular prognathism as a means for preparing a patient for dentures. This seems to be a radical procedure, but quite likely many patients would be willing to take the risks involved in order to have an improved appearance. The closest cooperation between the oral surgeon and the prosthodontist is essential.

—Carl O. Boucher



COMPLETE DENTURES

THE RECIPROCAL LOWER COMPLETE DENTURE

ARTHUR F. RUSSELL, D.D.S.
New York, N. Y.

THE UNSTABLE LOWER COMPLETE denture is a continuing problem for our profession. This problem has not been entirely solved. To the average general practitioner, it remains a puzzling uncertainty of daily practice. He finds it impossible to predict, with any degree of assurance, that a lower complete denture will be satisfactory when it is placed in the patient's mouth. This is a grave disadvantage when compared to the predictability of almost any other restorative service that he performs.

In the main, too much blame for failure, or for incomplete success, has been placed upon the patient. We have spoken of flat ridges and close muscle attachments, of softened tissues and lack of adaptability on the part of the patient instead of considering the possible shortcomings of our techniques. This attitude is neither scientific or just. This approach to a problem would not be acceptable to any other branch of medicine. It is not worthy of our profession.

What is a stable lower denture? It is simply one that is completely and continuously under the patient's control. The patient should be able to eat anything he desires with maximum efficiency and without the denture moving from its seat at any time. The patient should be able to speak normally without interference from, or movement of, the denture. The dentist cannot always deliver such a denture to his patient. He frequently depends upon a learning process on the part of the patient to enhance the usefulness of his product. Some patients never learn, and their dentures fail.

ANATOMIC AND PHYSIOLOGIC CAUSES OF FAILURE

Lower complete dentures that have been made with meticulous care by the most exacting techniques have failed because certain fundamental anatomic and physiologic facts have not been recognized. Success is possible only if these facts are considered in the technical procedures.

The buccinator muscles contain a strong central band of muscle fibers which after traversing the lateral face of the denture, turn sharply *inward* in the second molar region, thus strictly delimiting the distal end of tooth placement. The shape

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of the second molar tooth must conform to this limitation. In order to succeed, some dentures must be made with the second molar tooth omitted altogether, and it must be replaced by a wide, deep groove traversing the acrylic resin base from the buccal to the lingual margins in order to accommodate the buccinator muscle when it is flexed for the chewing stroke.

The angle formed by the lower anterior teeth and the anterior flange of the denture should correspond to the shape of the flexed form of the orbicularis oris muscle of the lower lip.

The modioli operate with great pressure in the region of the first bicuspid, extending as well into the region of the second bicuspid. Improper shape of the denture in this region is tantamount to dislodgement as soon as the patient's muscles are flexed for chewing or talking.

The tongue, when not at rest, may require a huge concavity in the lingual wall of the denture in the molar region, and this concavity may extend to the crest of the ridge. In this situation, the lingual sides of the posterior teeth should be cut away to conform to this concavity and to allow for free tongue movement.

A denture may fail because it is in conflict with the dynamics of the musculature. In other words, when the muscles of the lip, cheeks, and tongue are in action, they tend to unseat the denture. This is not accomplished, as has often been assumed, solely by the flexing of the muscles against the denture borders at their regions of attachment, but by a lifting action upon the teeth or the acrylic resin surfaces *wherever* the path of free motion of the muscles was restricted.

Muscle attachments are only parts of muscles. They are the narrowed or flattened ends of large, powerful muscle bundles. To have been taught how to avoid the muscle attachments without having been taught to avoid the muscles is like teaching a child to avoid the fender of a truck by stepping into the path of the truck itself. Only when we discard this ancient fallacy in favor of a truer picture of the entire musculature in action will we be prepared to render a professional denture service.

There are two cardinal principles regarding lower dentures:

1. A lower denture should occupy only that space which is not impinged upon when all of the muscles surrounding it are working.

2. There is an optimum shape and an optimum volume for each individual lower denture.

A reciprocal lower denture is one that cooperates with all of its muscular environment as well as it fits the ridge. When the muscles are in action, they tend to seat it more firmly, not to unseat it.

TECHNICAL PROCEDURE

In order to construct a reciprocal lower denture, it is necessary to make use of the principle of the wax pattern. A very soft wax must be used. This wax can be prepared by melting together, in a double boiler, two sheets of Kerr Tissue Seal wax and four level teaspoonsful of heavy mineral oil. These are stirred well and allowed to cool slowly to room temperature before using.

After impressions have been obtained in the usual manner and stone casts have been poured, the upper cast is laid aside temporarily. An acrylic resin baseplate is then cured on the lower cast by the usual flasking method using heat and pressure, as for a finished denture. This base must be a perfect representation of the ridge side of the finished denture. It should be of uniform thinness except for a slight excess of material at the ridge crest to serve as a strengthener against warpage. When tried in the mouth, it should present all the features of stability expected in the finished denture.

Fig. 1.

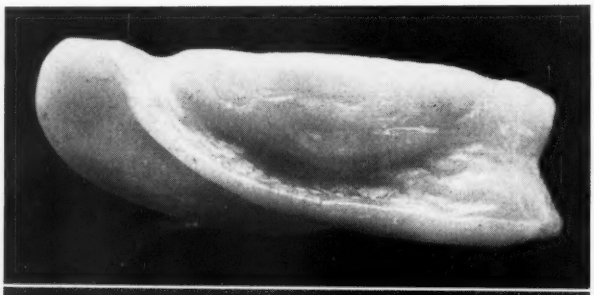

Fig. 2.

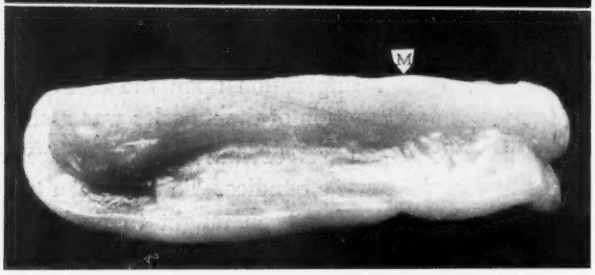

Fig. 1.—A soft wax pattern on an acrylic resin baseplate has been molded by the patient's lip and cheek muscles. Note the V-shaped profile in the anterior region which has been formed by the orbicularis oris muscle, and the horizontal groove in the posterior region that has been made by the strong central band of fibers of the buccinator muscle.

Fig. 2.—An anterior view (slightly turned) of the pattern shown in Fig. 1. The median line is at *M*. Note the depression made by the modiolus in the right bicuspid region and the profile of the left posterior segment.

The outside of the acrylic resin base is covered by a thin layer of sticky wax gently flowed on from a spoon spatula. A portion of the soft pattern wax is kneaded in the fingers until it has a putty-like consistency. It is then pressed onto the base in a rim that adheres to the sticky wax. This should not be the size of an occlusion rim. If too much wax is used, much unnecessary work will follow. The wax rim on its acrylic resin base should be shaped approximately to the size of an average denture.

The height of the anterior section should be at the level of the lower lip, and it should be not more than 3 or 4 mm. in thickness. It should then slant out and down in a wedge shape to both the inner and outer borders of the base. The posterior portion should have the width of a normal molar tooth and should be similarly wedge shaped, tapering out and down to the denture borders.

MOLDING THE WAX RIM

The patient must be taught to perform the necessary muscle movements. Two exercises are all that will be needed to carry the muscles through their useful paths. The whole of the labial and buccal surfaces can be molded by the familiar whistle-grin movement. The lingual surfaces are molded by placing the tip of the tongue in the upper buccal sulcus on one side and moving it to the opposite side and back again. The tongue is always kept as far as it will reach under the lip as these movements are repeated.

Fig. 3.

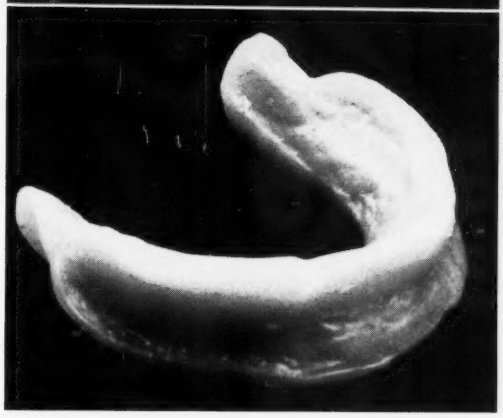

Fig. 4.

Fig. 3.—A lingual view of the pattern shown in Figs. 1 and 2. Note the modelling of the lingual surfaces as a result of the movements of the raised tongue.

Fig. 4.—The completed pattern is shown at an angle to bring out the detail of the left lingual concavity. (The wax pattern seen in Figs. 1-4 inclusive was selected because it portrays some of the hidden problems in lower denture construction. A more normal wax pattern can be seen in Fig. 5.)

The wax pattern, on its acrylic resin base, is placed in a pan of water at a temperature of 110°-120° F. for 3 minutes. The wax should become as soft as warm butter. Holding it by the acrylic resin base, it is carefully placed in the mouth.

The patient is asked to make the whistle-grin movement. After a few swings back and forth, the lip is gently pulled away from the wax and the face of the wax pattern is inspected (Figs. 1 and 2). The shape of the orbicularis oris muscle will

be registered, in most cases, as a trough or V-shaped groove running horizontally across the pattern from one first bicuspid region to the other. In the region of the first bicuspid on each side, a dish-shaped depression which has been formed by the modiolus will usually be noted.

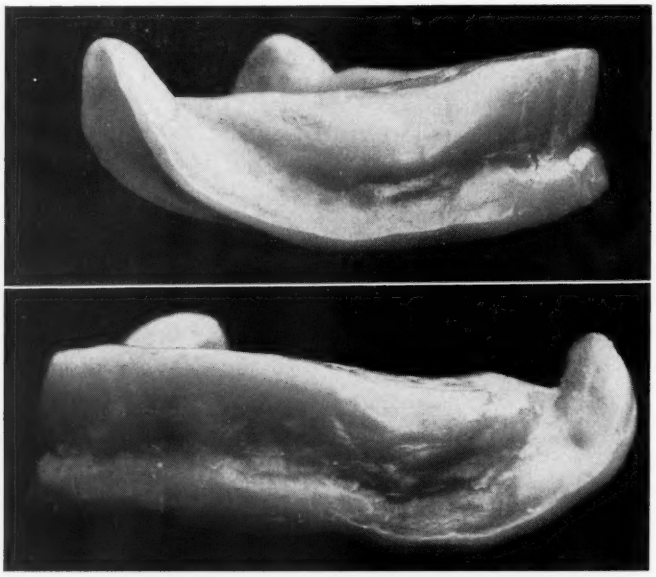

Fig. 5.—The right side is at the top; the left side is at the bottom. Right and left views of a fairly average wax pattern for a patient with a well-defined labial and buccal musculature. The imprint of the modiolus is more clearly evident on the left side. Note the intrusion of the buccinator muscles into the second molar areas. Compare with the occlusal view of the same pattern in Fig. 6.

Posterior to the modiolus, the shape of the buccinator muscle will appear in the wax in one of several forms. Typically, it will have cleared the wax from part of the buccal flange. Above the buccal flange there will be a double horizontal roll of wax with a groove between. This is the location where the strongest part of the muscle has been at work. The main bulk of the wax pattern will have been pushed lingually in all regions.

The patient is now requested to perform the tongue movements. The result of this molding will be a noticeable hollowing out of the lingual side of the wax pattern into a series of concavities (Fig. 3). After the tongue movement has been made several times, the face of the wax rim is again inspected. The bulk of the wax will now have been pushed labially and buccally, and many of the features previously noted will have been obliterated. When this occurs, it is a sign that the volume of the wax pattern is too great.

The anterior section must be trimmed with a warm knife on the lingual side following a whistle-grin movement. The posterior sections must be trimmed on the buccal side following a tongue movement. The objective is a pattern that is definitely molded on both the inner and outer surfaces and one that will not be deformed in

shape or position by either of the muscle exercises (Fig. 4). The internal and external muscle groups have been brought into play, moving them through their respective action paths. In so doing, reciprocating pressures have been exerted upon the soft wax, which is gradually molded into a state of neutral balance and becomes centrally inert in relation to all of the complex forces acting upon it.

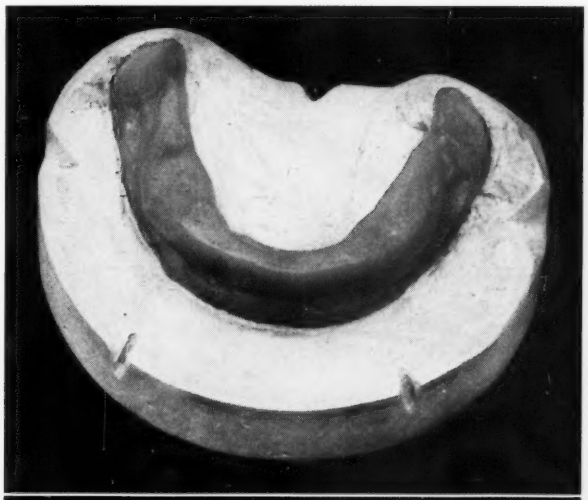

Fig. 6.

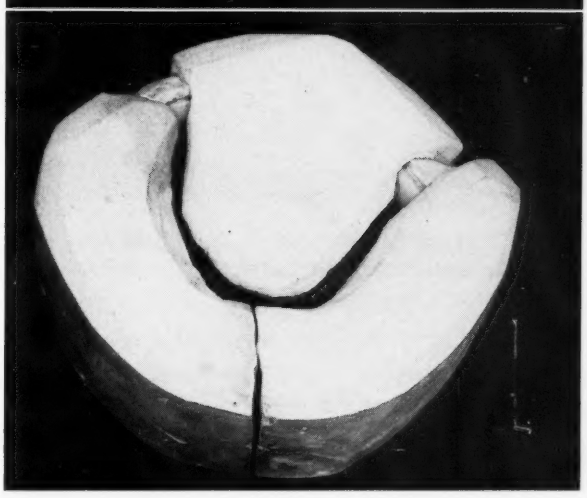

Fig. 7.

Fig. 6.—The pattern is seated on a stone platform which is notched.

Fig. 7.—A stone index is built in two sections to cover the wax pattern. The labial and lingual sections do not quite meet. The labial section is grooved at the median line so that it may be split.

The labial and buccal surfaces should show the anatomic details of the flexed muscles of the lip and cheeks. The lingual surfaces should show a definite imprint of the tongue. If too much wax is cut away by knife trimming, that portion of the pattern will remain glossy after the next molding instead of acquiring the charac-

teristic dull finish imparted by tissue contact. A little warm wax is added with a spatula, and the molding is repeated. If the base shifts in the mouth, either the volume of wax is much too great or the wax has not been softened sufficiently. The pattern may be removed from the mouth for inspection at any time. Also, it may be placed in warm water again for further softening, provided that both molding movements are performed subsequently.

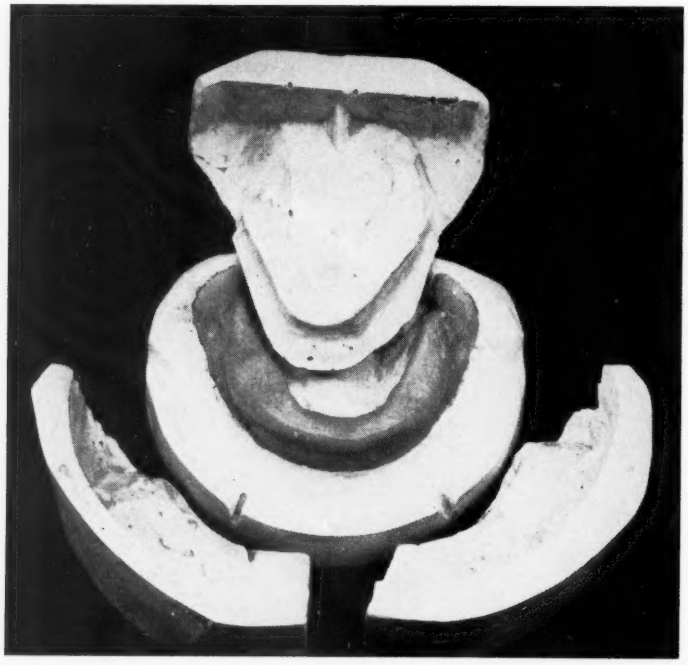

Fig. 8.—The index is separated into its three components, each of which is keyed into the notches of the cast. The shape of the finished denture is permanently established in this index.

When no alteration of shape or position can be made by the patient by means of either of the muscle exercises, the molding is complete and the pattern is acceptable as the optimum size and shape for that individual patient (Fig. 5). The pattern is well chilled with a stream of cold water. It is carefully removed from the mouth and placed in a pan of ice water.

THE STONE INDEX

The wax pattern, in its pan of ice water, is removed to the laboratory. The ridge surface of the acrylic resin base is lubricated lightly with petroleum jelly and artificial stone is poured into it. The base is then set down on a platter-shaped portion of the mix which extends at least one inch beyond the borders of the acrylic resin base (Fig. 6). Before the stone sets completely, it is notched. One notch is cut in the lingual center section, and two notches are made on each of the buccal sides, one in the cuspid and one in the molar region. The notches are made quickly.

The stone cast, the acrylic resin base, and the wax pattern are immersed together in cold water to avoid the effects of the chemical heat of the setting stone. The stone is coated with a separating medium when it has set hard, and the wax pattern is covered with a one-inch thick layer of a second mix of stone which is worked into the notches of the base. This is done in two sections, leaving a narrow dividing line of wax at the occlusal and incisal edges of the pattern so that the lingual and buccal sections of the stone index do not quite meet (Fig. 7). The heat of setting stone is controlled by placing it in a pan of cold water.

When this second mix of stone has hardened, the index can be split at the median line on the labial side. The buccal and labial portion may be removed in two sections. The lingual portion may be removed as a single piece. The shape of the denture is now permanently registered in this stone index (Fig. 8).

THE HARD WAX OCCLUSION RIM

The soft wax pattern is now destroyed down to the bare acrylic resin base. The stone index is soaked in water and the excess is blown off. The index is then coated with a light mineral oil and assembled with the acrylic resin base in position. Pink baseplate wax is slowly melted in a ladle and poured into the index through the space between the labial and lingual indices on the occlusal surface. Then the entire assembly is immersed in cold water. When the index is opened, a hard wax duplicate of the soft wax pattern has been formed. This is easily handled, and being attached to the acrylic resin base, it becomes the lower occlusion rim. The usual occlusion rim on a stabilized base is constructed on the upper cast.

The maxillomandibular registrations are made by the usual techniques with the important proviso that all adjustments must be made in the upper occlusion rim. There is one exception to this rule. In the rare event of the lower rim being so high in the molar region that it leaves insufficient space for the setting of the upper molar teeth, the occlusal surface of the mandibular wax rim may be carefully shaved down before the registrations are made. The lateral surfaces must not be disturbed.

The completed registrations are transferred to the articulator. The lower cast is merely luted to the base of the articulator with a definite plaster seat. It is immediately freed from this seat and returned to the index which has remained independently on the bench. Any deformity of the lower wax rim which may have occurred during the making of the maxillomandibular registrations should be corrected at this time.

ARRANGEMENT OF THE TEETH

All of the lower teeth are set first. This is done by removing just enough wax to set one tooth at a time, constantly checking its position with the index. The anterior teeth and the labial surface of the supporting wax must reproduce the exact shape of the flexed orbicularis oris as it was registered in the pattern. The bicuspid teeth must be set similarly with regard to the modioli and the beginning of the buccinator registration. Their lingual surfaces must correspond to the lingual portion of the index.

The molar teeth are then fitted very carefully into the remaining available space within the index, and their supporting wax retains the exact buccal and lingual contours registered in the index (Fig. 9). In no instance may the external contours of the teeth or wax violate the shape that has been so carefully established. Careful selection of teeth will often obviate excessive grinding, but sometimes the molars must be narrowed drastically to fit within the index.

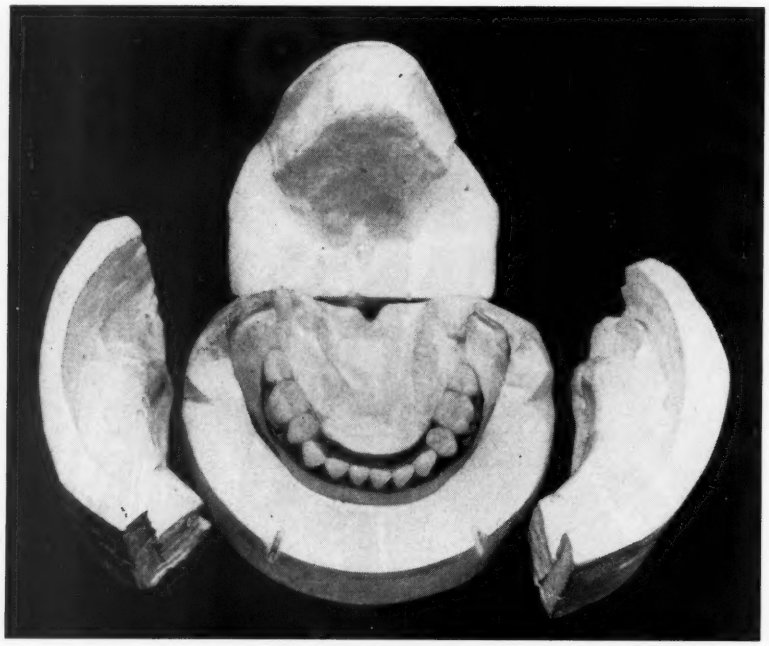

Fig. 9.—The teeth have been set to conform to the stone index. The wax supporting the teeth also follows the contour of the index both labially and lingually.

When all of the lower teeth have been set, the cast with its waxed set-up is returned to the articulator, and the upper teeth are set. It should be obvious that a set of dentures is being constructed wherein every effort has been directed toward the construction of an ideal lower denture instead of the usual method of considering both upper and lower dentures in the selection and arrangement of teeth. This is possible because a certain amount of leeway is permissible in setting upper teeth without unsettling an upper denture, and the occlusal height of the lower posterior pattern is relatively unimportant as long as it is not increased. It may be reduced with impunity in order to accommodate upper molars if the lateral sides are undisturbed.

A little experience with the molding of soft wax patterns will enable the dentist to avoid later difficulties. In the rare instance where the posterior wax seems to be too low, the following should be considered: (1) The original height of the wax before molding may have been insufficient. (2) The patient may be making unauthorized tongue movements out of curiosity. (3) The vertical dimension of the bite may have been made too great.

A patient with an exceptionally powerful musculature, both buccally and lingually, will produce a typically pyramidal molar pattern which rises to a knife edge. This will always be too high rather than too low. It should be cut down to achieve the following objectives: (1) The apex of the pyramid must be cut off until sufficient width is obtained to allow for a narrow occlusal surface. (2) The best possible relationship with the position of the upper teeth must be borne in mind.

ARRANGEMENT OF THE UPPER TEETH

In the arrangement of the upper anterior teeth, the requirements of appearance are paramount. If a horizontal overlap occurs, it should be disregarded. The upper posterior teeth are arranged to produce the best possible occlusion with the lower teeth. Since the lower occlusal surfaces may be reshaped freely, and since the upper teeth can be moved freely, the maximum occlusal contacts can be attained.

THE TRY-IN WAX TRIAL DENTURES

The wax trial dentures are tried in the mouth to check the appearance and occlusion. The patient's reaction will be favorable when he feels the lower trial denture in his mouth. This is likely to be particularly evident in those patients who have experienced several denture failures. The patient's usual query is whether the finished denture will feel as good as the trial denture.

COMPLETION OF THE DENTURES

The upper denture is finished in the usual manner.

A stone cast is poured carefully into the impression surface of the acrylic resin base of the lower trial denture. This is then flasked in the usual way. After the flask has been separated and the wax removed, the acrylic resin base is softened by directing a Bunsen flame against it. The resin base is then removed from the flask and the mold is packed with all new denture base material. This will avoid warpage of the original base during processing. The finished lower denture must be polished very lightly and with extreme care.

GENERAL OBSERVATIONS

A great many failures in the stability of lower dentures have been attributed to flat lower ridge areas. These dentures are described as "skidding" on their supporting tissues as the result of maxillomandibular forces exerted during the process of mastication. This may be etiologic confusion.

The observation of many wax patterns of edentulous mouths indicates that the skidding of dentures is more likely to be a result of dynamic muscle imbalance than of the forces exerted by the opposing teeth. The typical flat residual ridge is surrounded by a powerful musculature which works on a great area of the denture and with direct dislodging leverage against improperly shaped lateral denture surfaces. If these lateral denture surfaces are contoured to the correct size and shape, a denture with a flat basal seat area will be firmly held in place by the working muscles. Its stability will be equal to that of a denture supported by a high ridge.

A reciprocal denture is held in place by the reciprocating action of the flexed muscles which surround it. At the beginning of a chewing stroke, the action of the orbicularis oris, the modioli, and the buccinator muscles against the outer surfaces of the teeth and their precisely contoured acrylic resin flanges tend to seat the denture and to press it gently backward and inward. The opposing force of the tongue whose sides and underparts are wedged against the lingual surfaces of the teeth and the scooped-out lingual flanges tends to seat the denture and to press it gently forward and outward. The exact balance between these muscle forces enables the patient to hold the denture firmly in place.

Where the posterior ridge is badly shrunken, the resorption of bone frequently leaves a semblance of a ridge on the lingual side and a flat buccal shelf. In these instances, the tongue will push the soft wax pattern buccal to the *apparent* ridge and directly over the buccal shelf. It would be fatal in this situation to follow the rule which demands that molar teeth be placed directly over the ridge. The wax contour should be followed, narrowing the molars considerably and placing them over the buccal shelf as close to the ridge as the imprint of the tongue will allow. Although this tooth position has caused the failure of dentures made by other techniques, it will be uniformly successful if the correct muscle balance has been obtained.

SUMMARY

1. The functional instability of many lower complete dentures is due to a conflict between their external contours and the working muscles of the lip, cheeks, and tongue.

2. A technique for registering the dynamics of the musculature in a direct wax pattern has been described.

3. A stone index of this wax pattern is made.

4. The complete lower denture is designed to fit within the index.

5. The technique provides for the construction of an *ideal* lower denture and the opposing upper denture is made to conform to it.

I acknowledge with gratitude the assistance of my technician, Mr. John Postogna, in the development of the technical phases of this procedure.

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CENTRIC RELATION AND FUNCTIONAL AREAS

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CENTRIC MAXILLOMANDIBULAR RELATION IS the normal static relation of the mandible to the maxillae, the glenoid fossae, and the neuromuscular mechanism. The position is three-dimensional, including height (vertical), width (lateral), and depth (horizontal).

Dental rehabilitation and prosthesis require the diagnosis and registration of the vertical dimension, centric relation, functional areas, and a torsion-free maxillomandibular relation. A current definition of centric relation is, "The most retruded relation of the mandible to the maxillae when the condyles are in the most posterior unstrained position in the glenoid fossae from which lateral movement can be made at any given degree of jaw separation."[1] This definition is based on technical registrations which may be used for dental treatment. Reference is made to vertical dimension which must be established previous to making a horizontal registration, since the horizontal position of the body of the mandible to the maxillae changes with any change in vertical dimension. Some techniques permit a change of vertical dimension to be made on the articulator because the procedure includes an effort to place the casts on the habitual closure axis, or on any of the hinge axes desired for the chosen technique.

Diagnosis for vertical dimension should include a minimum of 2 mm. of freeway space (interocclusal clearance), esthetics, phonetics, efficiency of biting force, consideration of previous vertical dimensions, and the type of occlusion.

CENTRIC OCCLUSION

Centric occlusion is established in conjunction with centric jaw relation. The objectives are: (1) an occlusion in harmony to the musculature and the temporomandibular joint function, (2) a centric occlusion to which the mandible is directed in mastication, and (3) a centric occlusion providing the proper relation in swallowing and in closing from physiologic rest position.

In patients where the occlusion, musculature, and temporomandibular joint have been in normal function, the centric relation of the mandible and the functional relations of the mandible are closely related. The current definition of centric relation suggests that the most posterior unstrained position of the condyles be used for establishing centric occlusion. This position may be recorded by the needle-point tracing, occlusion rims, and the posterior terminal hinge-axis techniques. All of these produce posterior *perimeter* registrations. All movements of

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the mandible are forward or lateral from this posterior position; therefore, the occlusion can be within the balancing range of the mandibular movements.

One of the problems is that if teeth with cusps are used, the occluding contacts are on inclined planes as soon as the cusps are moved away from the opposing central fossae. If the mandibular movement is directed at a location other than the recorded centric relation, the tooth will receive a lateral thrust because of the contacts on the inclined planes of cusps.

In normal cases, the unstrained posterior position, the horizontal position where maximum force is applied, and the position of closing from rest position are about 0.5 mm. apart. Any one of these positions may be used as centric relation, and by freeing the occlusion at the centric relation 0.5 mm. in all directions, the entire range of physiologic centric occlusion will be included.

In function, centric occlusion becomes a dynamic entity, and it must reflect the conditions present at the time of treatment. The abnormal cases may include a malfunction which has caused considerable change in the anatomic structures. Some patients have the mandible forced into a posterior displacement by malfunction, and a posterior perimeter registration would then record the posteriorly displaced position.

The stomatognathic system is biologic, and it may be changed by malfunction. It is not a mechanical, fixed system with fixed relations under all conditions of function.

FUNCTIONAL AREA

Because of the importance of function in mandibular positions, a third step should be added to maxillomandibular relation registrations. This step would be the location of the functional area. The procedure for such a technique would involve the registration of muscle function or dynamic movements. One method is to seat the patient erect with the head in a normal upright position, after the vertical dimension has been established. The registration is made by a tapping movement. The patient would then follow this by masticating movements. Observations are made to establish the extent of the functional area in relation to the recorded centric relation.

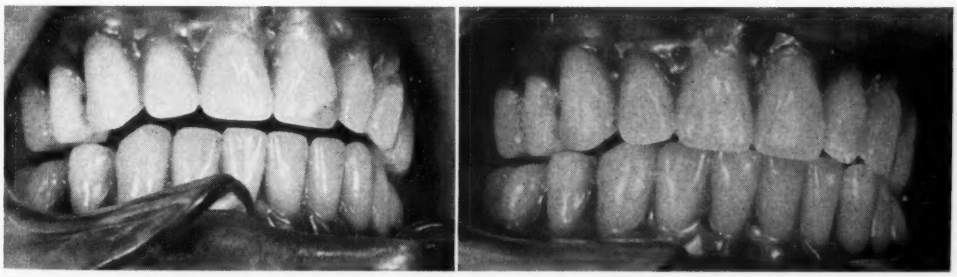
Another method involves the use of a gnathodynamometer,[2] which permits the free movement of a central bearing point on a bearing plate. The patient is able to locate the most desirable functional area and record the maximum closing forces in that area. The position of this functional area would then be related to the unstrained posterior position (centric relation) to establish the range of movement and prescribe the total functional area. Usually, the function occurs in the region of the unstrained posterior relation. However, there may be as much as 7 mm. variation from the apex of a needle-point tracing, or the posterior terminal perimeter, to the position of the functional area (Fig. 1).

When the functional area is within 0.5 mm. of the apex of the needle-point tracing (the posterior terminal axis), it is possible to use the posterior location for establishing the centric occlusion and include the functional area in the centric occlusion by selective grinding and milling. The centric occlusion is then free to move at least 1 mm. in the general area of centric relation.

When the functional area is located more than 1 mm. from the posterior relation, the problem of occlusion becomes greater. In following a technique which makes use of the posterior location for the centric relation, it is necessary to provide a balance of occlusion which will be extended to include all of the functional positions. Usually, cusp teeth will become practically flat cusp teeth or a mechanical type of teeth when they are ground into harmony with these extensive movements while maintaining a right angle surface to the various vertical strokes of function. The right angle contact surfaces return the vertical closing force to the ridges. For this reason, it is often advisable to use a mechanical or cuspless type of tooth for patients who have extensive functional areas of contact.

Fig. 1.—The functional area is indicated by the power points and related to the apex of the needle-point tracings. *Left*, the functional area is close to the apex; *right*, the functional area is several millimeters from the apex.

Another technique for recording centric relation makes use of the normal physiologic rest position.[3,4] The vertical relation is decreased on the habitual closure axis to create free-way space (interocclusal clearance); and the centric occlusion is thereby established.[7]



A. *B.*

Fig. 2.—*A*, The horizontal overlap of the anterior teeth is 4 mm. because the functional area is 4 mm. from the apex of the needle-point tracing. *B*, When the dentures are in function, the horizontal overlap is reduced.

HORIZONTAL OVERLAP

A horizontal overlap is an important factor in the occlusion. Approximately the same amount of horizontal overlap as the measurement from the centric relation to the anterior perimeter of the functional area is suggested. If this distance is 5 mm., there would be approximately 5 mm. of horizontal overlap. In this way, the mandible may move within the functional area and still maintain a normal rela-

tion between the anterior teeth. Because the patient is able to function at the centric relation and within the functional range, the occlusion of the prosthetic restoration is balanced throughout the required occlusal area (Fig. 2).

CHANGES IN RELATIONSHIPS

Over a period of time, some patients seem to respond to the occlusal correction, and consequently, the terminal functional area of closure and centric relation assume a more normal and close relation to each other. This change may indicate that the terminal functional area has moved toward the centric relation, or the so-called centric relation has moved toward the functional area. Accepting the thought that the posterior centric relation is normal, we would assume that the functional area moved posteriorly. However, in dentulous patients, a posterior displacement of the mandible is possible. Given the opportunity, the mandible may function in a more normal protrusive relation, and eventually the posterior thrusts are reduced.[6] The so-called protrusive relation becomes the normal centric relation. Evidence of this has been present in the diagnosis of patients who have a posterior thrust on the mandible because of the occlusion which has been treated subsequently with removable onlay splints. A posterior displacement of the mandible by as much as 6 mm. has been noted. After 3 months, the patient was not able to return the mandible to the posterior position, and this would indicate that the so-called centric relation had moved forward when it was given the opportunity by freeing the occlusion (Fig. 3).

Since there is evidence of these functional conditions and changes, it would seem reasonable that patients, with occlusions which might produce posterior displacement of the mandible, should be treated for some time with the objective of removing the possibilities of such malposition and malfunction. The mandible will seek its normal relation, and the changes which take place would provide a more normal relationship of the mandible to the maxillae.

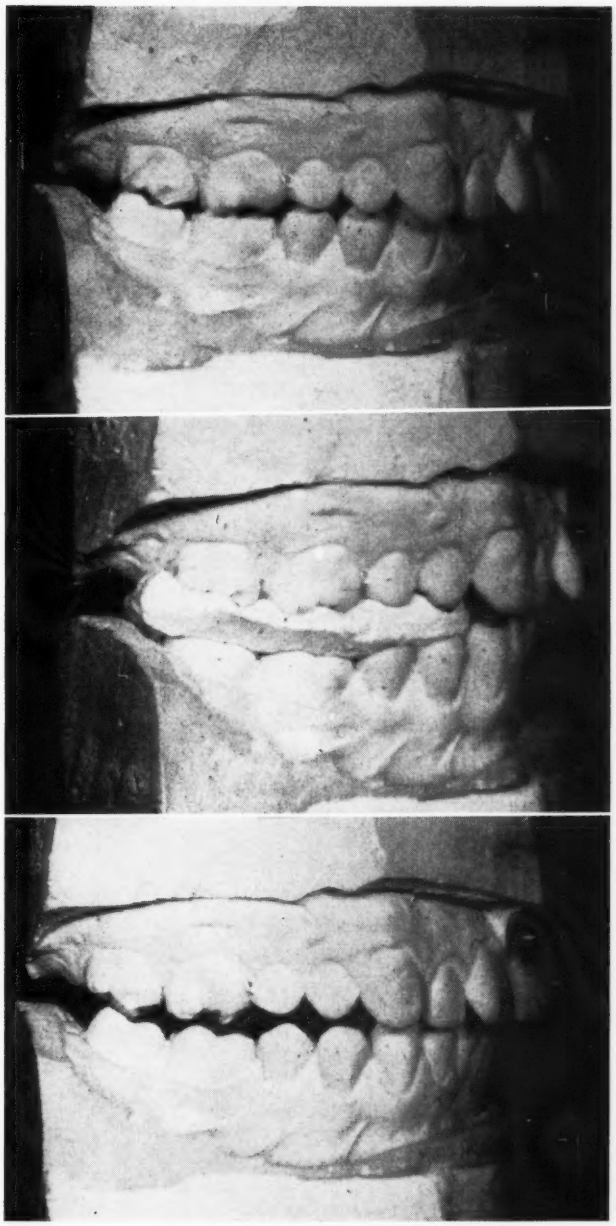
In patients with normal occlusion, the centric relation seems to be in the same approximate location regardless of the techniques used for making the registration.

CONDITIONING

Because patients who require treatment usually have considerable malfunction, all patients should have a conditioning period before final restorative procedures are instituted. Muscle therapy may be prescribed as the muscles are more readily returned to normal than are the other structures. Oral conditions and psychologic factors are evaluated, and a reference is made to the general systemic condition of the patient. Conditioning treatment may be considered as the first procedure of dental rehabilitation.[5]

REGISTRATION OF CENTRIC RELATION

It is important to avoid torsion at the time the centric-relation registrations are completed for transfer to the articulator. Materials, such as wax or modeling compound, which require the application of force for making the registrations, may tip



A.

B.

C.

Fig. 3.—*A*, The relationship of the posterior teeth indicates a possible posterior displacement of the mandible. *B*, The physiologic rest position is recorded by means of a plaster of Paris interocclusal record. *C*, Habitual closure from rest position to the first contact of the anterior teeth has been made. Note the forward position of the mandible.

or displace the mandible. Unstrained relations can be recorded with plaster of Paris, zinc oxide and eugenol pastes, or similar materials because they require no force for making the registration.

SUMMARY

Centric relation records should include not only centric relation, but also the vertical dimension of occlusion, the range of functional areas, and they should be torsion-free. In this way, a maxillomandibular relation will be determined which has the greatest efficiency for a functional occlusion and mouth rehabilitation.

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HUMAN TOOTH FORM AND ARRANGEMENT FROM THE ANTHROPOLOGIC APPROACH

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THE CONCEPT PREVAILS IN dental teaching that the occluding surfaces of the posterior teeth should retain the same form throughout their lifetime that they had at the time of eruption. While it is considered normal for the mamelons to wear off of the anterior teeth, the cusps of the posterior teeth are expected to remain as they were when they erupted. This concept of intact and well-defined cusps is evidenced by most articles and textbooks on restorative dentistry, chiefly those dealing with operative procedures and fixed partial denture restorations. It has permeated the profession to such a degree that it is a basic tenet upon which many phases of dental procedure are built. If teeth are worn, obliterating the cusps partially or completely, the condition is considered to be pathogenic, and measures are advocated to restore them to their unworn form.

THE UNWORN TOOTH CONCEPT

The dental profession became very conscious of the unworn tooth form when Black[1] wrote his textbook on dental anatomy. Early in his dental curriculum, a student is taught dental anatomy and the carving of teeth out of plaster, ivorine, wax, or some other medium. This is designed to inculcate in him a knowledge of tooth form. From this preliminary training, the student progresses until he makes inlays, crowns, and pontics. In prosthodontics, he is introduced to tooth arrangement by the setting of teeth, usually with well-defined cusps, to a pattern which implies that teeth function better by this arrangement (Fig. 1).

MECHANICAL ERA

Dentistry is in the midst of a biologic era. It is emerging from a period where triangles, cones and spheres, together with ellipsoidal and arcuate figures were used to express human and anatomic forms as well as tooth arrangement and mandibular movements (Fig. 2). Dental pioneers like Bonwill, Monson, and Hall influenced this type of dental thinking, some of which persists to this day.

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Gysi[2] altered artificial posterior tooth design from relatively flat forms to those dictated by Black's studies. By an ingenious method, he produced balanced opposing artificial dentures. He used four strips of metal which had been cut to imitate shark's teeth. Actually, they resembled the teeth of a rip saw (Fig. 3). These strips were set in plaster on one member of an articulator. The opposite member of an adjustable articulator held a block of plaster. By scratching the "shark's teeth" into this plaster, imitating mandibular gliding movements, and by some additional sculpturing he was able to design teeth which, with some modifi-

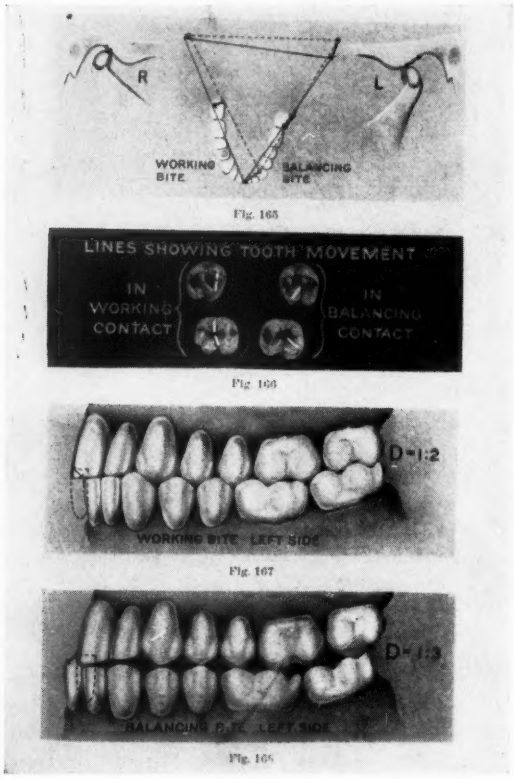

Fig. 1.—The arrangement of cusp teeth in a definite pattern. (From "Professional Denture Service" by G. W. Clapp and R. W. Tench, 1918.)

cation, not only conformed to Black's formula of human tooth form but could be arranged on an adjustable articulator in balanced occlusion (Fig. 4). To prove that the method was "scientifically correct," he demonstrated geometrically how the size and shape of each facet were obtained (Fig. 5).

Later, in a very similar manner, but with a much improved technique, McCollum was able to carve occlusal surfaces for the teeth of each individual patient using an anatomic articulator of great accuracy. He created the occlusal forms on prepared teeth in such a manner that there was continuous contact of opposing teeth in practically all positions of the mandibular gliding movements. He produced a finely integrated, coordinated interplay of cusps and grooves.

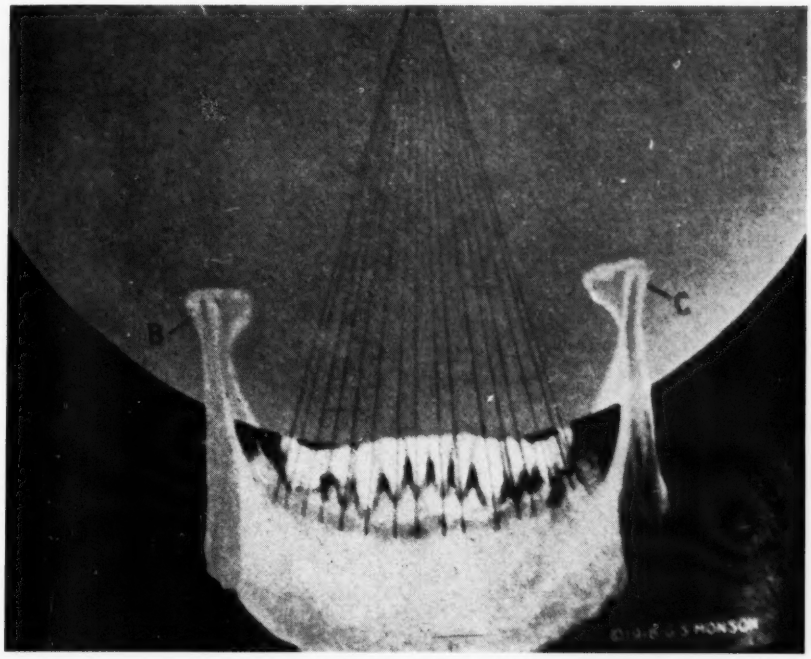

Fig. 2.—Monson's concept of an ideal tooth arrangement. (From Monson: "Occlusion As Applied to Crown and Bridge Work," J.A.D.A. **7**:400, 1920; previously published in Moses' "Studies in Articulation," J. PROS. DEN. **2**:326, 1952.)

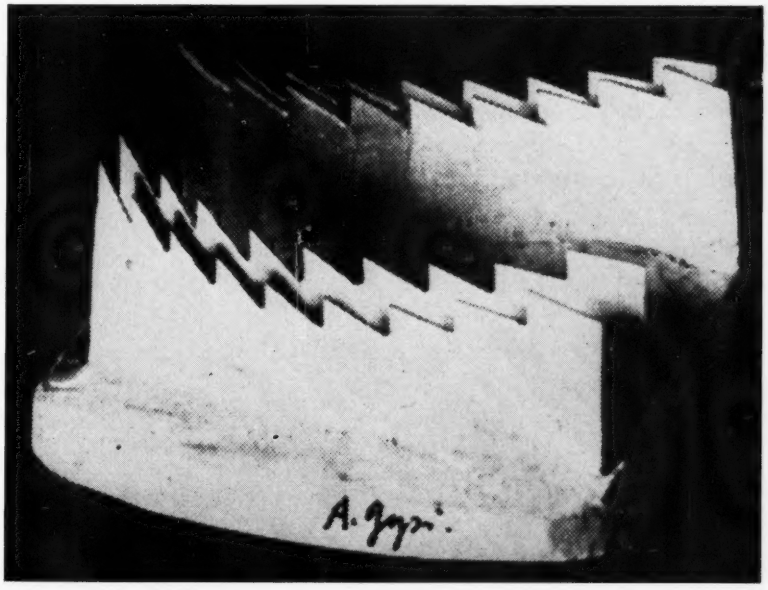

Fig. 3.—Gysi's "shark's teeth" were used in his preliminary steps in the carving of anatomic tooth forms. (From Gysi: "Practical Conclusions From Scientific Research in Denture Construction," New York, 1929.)

But, accurately created an ingeniously evolved as these methods were, they did not portray natural tooth conditions. There is a difference between form as dictated by artificial means, even though acceptably complying with physiologic requirements, and form as created by evolutionary developments. As far as is known, from billions of people who have inhabited this earth, no one has ever discovered a natural dentition whose unworn cusps occluded in the beautiful fashion artificially produced by Gysi and McCollum. The fact that physiologic results may be obtained by so-called anatomic articulation does not mean that the form and arrangement so devised are "normal." It only means that this particular artificial phenomenon conforms to some natural laws. The mere use of teeth formed in accordance with the patterns described in a dental anatomy textbook does not signify that they could be used in an accurate harmonious relationship. With McCollum's method, cusp height and form are designed to conform with all the other factors of occlusion, some of which are fixed in the individual patient. Gysi himself pointed out, as did many others, the destructive capacity of high cusps which are not coordinated with all mandibular movements.[3,4] Flatter cusps, both natural and artificial, appear to be less destructive to related tissues, on an average.

The purpose of this article is to examine natural tooth form and arrangement from the anthropologic approach and, if possible, to discuss them from the viewpoint of the dentist.

FUNCTION, FORM, AND ENVIRONMENT

All living organisms thrive better in the environment to which they are adapted. An environment is rarely, if ever, constant. Therefore, mechanisms usually have been created to permit the organism to conform to a changing environment. Some of these mechanisms took millions of years to develop, originating in lower forms of life. Some were devised to meet *immediate* changes in an environment, often employing minute histologic alterations accompanied by chemical and other changes. However, gross changes of form accompanied by other features were developed over a longer period of time and in surroundings which altered more slowly.

As a general rule, form and other mechanisms were developed *specifically* for a particular organism and its environment. Some organisms prefer land, some water, some need oxygen, some are anaerobic; some thrive best in an acid medium, and some like an alkaline medium. Each has not only developed or altered a form to suit a specific environment but has also formed organs and developed chemical and other special mechanisms. Skeletal bones, nervous and vascular systems, organs, and muscles are not only created for, but to comply with the needs of the total organism to meet an environment. Thus, there is not only specificity of the form and function of an organism but of each part of the organism. The structures of the masticatory apparatus were thus evolved. To be more explicit, the form and location of each tooth in the human masticatory apparatus has been evolved because there was a need for that form, and it is placed in a certain position and at a certain angle because it is or was necessary to be in that location and at that angle. This is not predetermination, but adaptation.

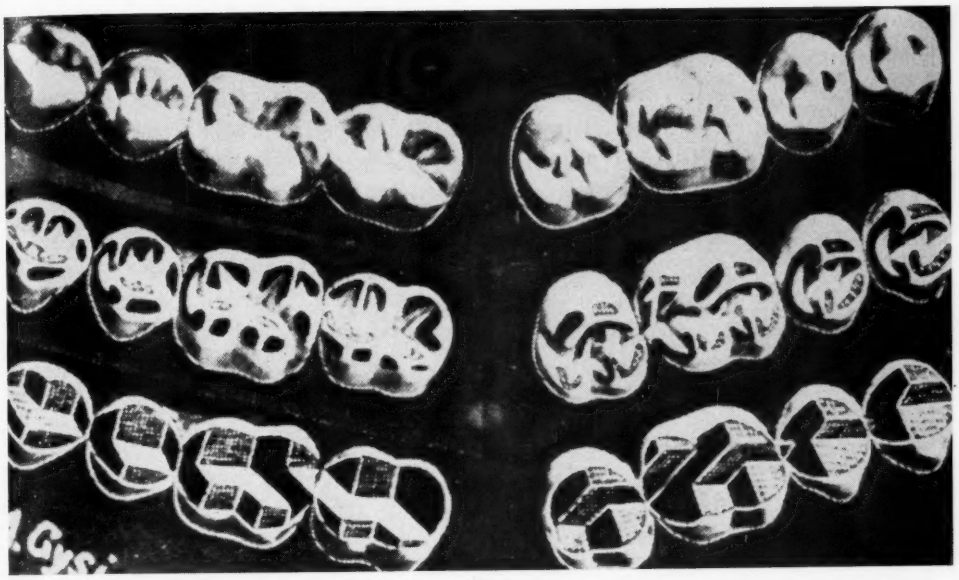

Fig. 4.—Various stages used by Gysi in the development of anatomic tooth forms from the grooves scratched into the plaster blocks by the "shark's teeth." (From Gysi: "Practical Conclusions From Scientific Research in Denture Construction," New York, 1929.)

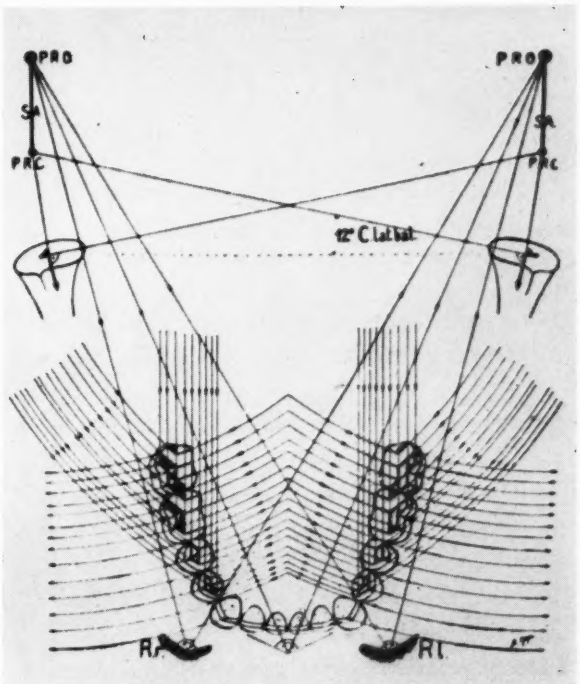

Fig. 5.—Gysi's geometric explanation of the way he determined the size and shape of each facet. (From Gysi: "Practical Conclusions From Scientific Research in Denture Construction," New York, 1929.)

It is in keeping with principles learned from anthropologic studies to expect that the unworn posterior teeth at one time had a definite function. They would not have been formed in that pattern otherwise. It is also very realistic to accept the fact that in nearly the total time that man has been on earth wear has taken place more or less extensively, altering the pattern. He has lessened the wear on his teeth only in comparatively recent times when he learned to cultivate and process his food. Consequently, today, in some sections of the world, man's teeth have little or no wear. This phenomenon has occurred only in recent centuries, while for almost the total portion of a million or more years, wear had always been present. From an evolutionary standpoint, insufficient time has elapsed for nature to create new mechanisms to cope with the absence of wear in the last several hundred years.

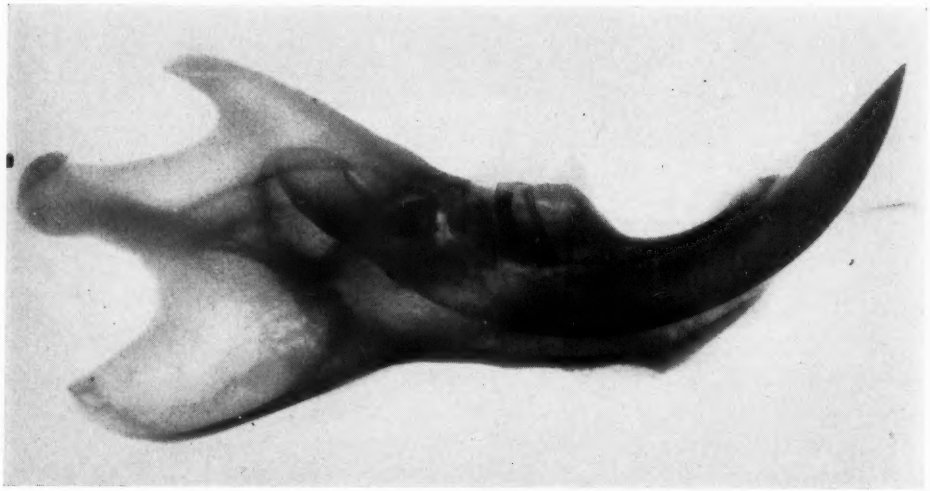

Fig. 6.—The incisor of a rat erupts continuously while wear takes place. However, new tooth substance is developed continuously at the root end of the tooth.

Nearly all teeth from prehistoric and primitive people manifest wear. During man's existence, however, mechanisms were developed both to compensate for, and to take advantage of wear.

In most lower animals whose teeth exhibit considerable wear, an eruptive compensatory mechanism has been developed. As a rule, this is sufficient to provide efficient function for the lifetime of the animal. The incisors of rats have evolved a mechanism of rapid continuous eruption made necessary because they are always gnawing abrasive substances. However, new tissue is developed continuously at the end of the root while the entire tooth is pushed forward (Fig. 6).

In man, the erupting mechanism need not be as rapid and as vigorous since his life span, until recent years, was relatively short, and abrasive elements were not as severe as those used by the rat. Consequently, new tooth substances were not created at the root end. As the teeth wore down, they continued to erupt; at the same time, they maintained the line of occlusion. An important point to consider

is that in nearly all structures of the body which are subject to considerable use, a repair mechanism is usually present. With human teeth there is no repair of the the worn-out tissues. Rather, there is a deposition of a material internally and a new chewing, triturating surface is created by the wear.

MECHANISMS DEVELOPED BECAUSE OF WEAR

Continuous Eruption.—Each human tooth continues to erupt until it meets opposition. As a tooth erupts, bone is proliferated at the gingival crest. Therefore, a healthy tooth in a healthy periodontium rarely leaves its socket. It is not uncommon to see teeth worn down almost to the gingivae but with the bone very robust and high. If it is unopposed, the tooth, accompanied by the alveolar process, will erupt beyond the line of occlusion. It is safe to assume that the eruptive process was developed because of wear. With worn teeth, the alveolar process is not only high, as we have pointed out, but the distance between the nose and the chin is maintained.

Calcific Deposition in the Pulp Chamber.—Wear on human teeth frequently progresses as far as the pulp chamber. Nature developed an internal defense against this wear by laying down a calcific deposit and causing a recession of the pulp as the wear progresses. This recession sometimes obliterates the pulp chamber completely. This deposition also takes place in modern society because of stimuli from thermal, bacterial, or other irritants in the presence of decay and under fillings and crowns, as well as by wear. Wear is also possible despite our modern diet which lacks in abrasive substance, but this is due generally to hypoplastic enamel.

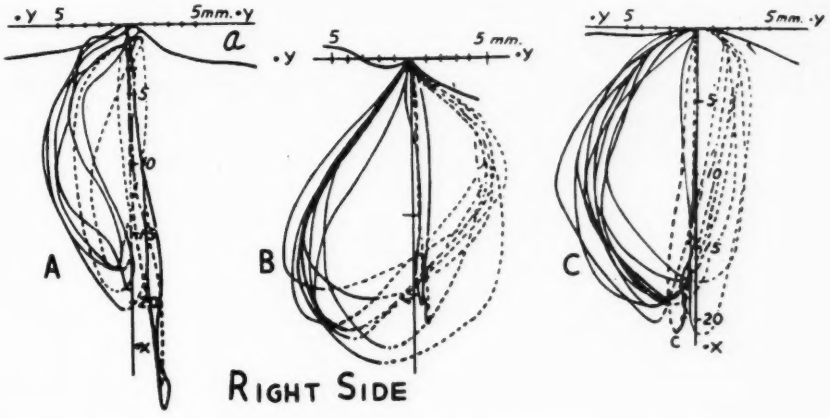

Fig. 7.—The chewing cycles first demonstrated by Hildebrand. Note that the cycles at the right are flatter at their peaks. This might be because of worn teeth. (From G. Y. Hildebrand: "Mandibular Kinetics," J. D. Res., December 1937; previously published in Moses' "Biomechanics and Artificial Posterior Teeth," J. Pros. Den. 4:782, 1954.)

Trituration and the Chewing Cycle.—Herbivorous animals chew their food while carnivorous animals, because of their limited pure hinge movement, cannot chew. They shear off the food and swallow. This is a very important observation because the lateral or horizontal component of masticatory movement seems to be

necessary in nature for chewing purposes. Herbivorous animals that appear to have a lateral chewing motion actually employ a vertical chewing cycle as demonstrated by Hildebrand.[5,6] The cycle flattens slightly near the top.[7] The inclination or pitch of the occlusal surface seems to influence the chewing pattern, according to Hildebrand's illustrations. This flattening of the pattern leads me to believe that some horizontal movement is necessary in chewing. Shearing is generally done in a straight line. *Thus, chewing must be differentiated from shearing.* The chewing cycle in man is similar to that of the herbivorous animal except that it is narrower and it terminates in a point, as demonstrated by Hildebrand,[5] Boswell,[8] Payne,[9] and Kurth[10] (Fig. 7). However, I suspect that had the patient been an Eskimo, with a flatter chewing surface and tougher food, the chewing cycle might have terminated in a much flatter pattern near the top and perhaps it would be wider, like that of the herbivorous animal in Hildebrand's illustration (Fig. 7). The angulation of the slope of the chewing surface and the steepness of the cusps seem to influence the shape of the chewing cycle. Perhaps the nature of the food is also a factor.

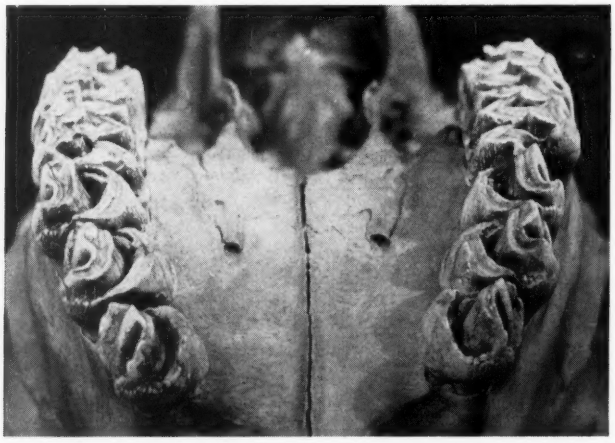

Fig. 8.—Teeth of herbivorous animals have folds of enamel which enclose softer dentine that wears away faster than the enamel. Thus, cutting knives and food escapes are formed.

Herbivorous animals must comminute their food thoroughly in the mouth. Consequently, they have developed an efficient chewing mechanism which maintains its efficiency. There are folds of enamel which enclose softer dentine. The dentine, wearing out more rapidly than does the enamel, creates food escapes while the folds of enamel form sharp knives (Fig. 8). In human teeth where wear exists, the enamel usually wears through and the softer dentine often cups out, creating food escapes and leaving harder knives of enamel in various places on the tooth. This forms a very efficient triturating mechanism (Figs. 9, 12, and 18). There are some instances where perfectly smooth surfaces have been observed even though considerable wear has taken place. Could it be that, in these instances, the enamel was hypoplastic in nature and the rate of wear was the same as that of dentine?

Shearing and the Chewing Cycle.—It has been established that well-defined cusps produce a very efficient shearing mechanism. Probably this was evolved from

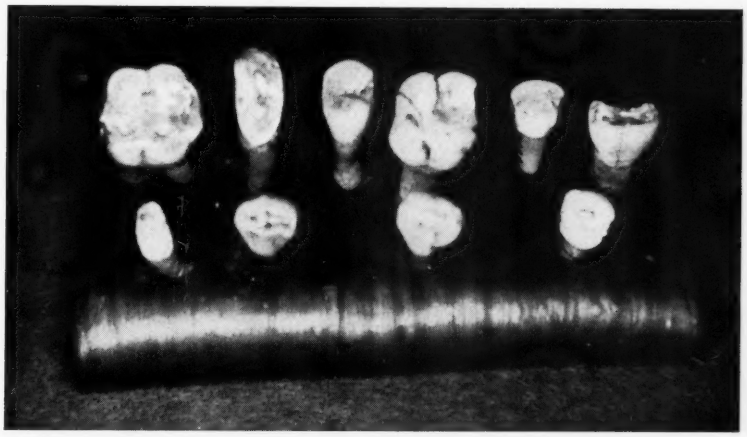

Fig. 9.—Teeth found in a 700-year-old Indian burial ground at Tabor Hill, a suburb of Toronto, Ontario. Varying degrees of wear and a variety of patterns of wear were found. (Courtesy Royal Ontario Museum.)

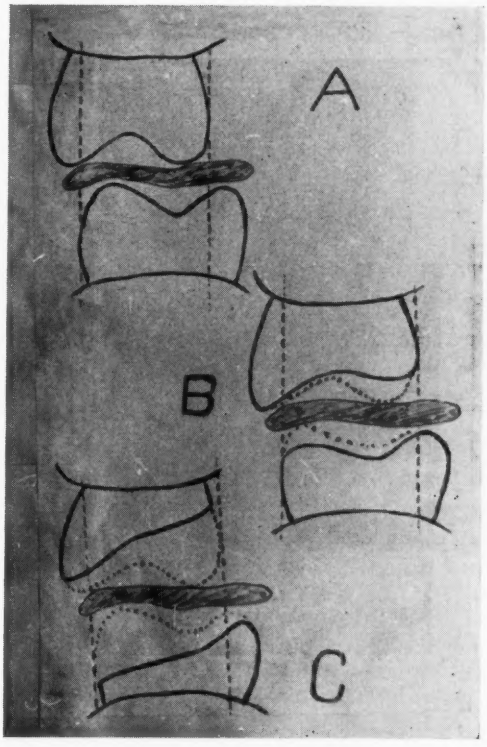

Fig. 10.—The various stages of wear. The commonly contacting surfaces wear first. Wear usually takes place on the buccal cusps and buccal side of the lower posterior teeth and the lingual cusps and lingual side of the upper teeth. This not only conforms to the pattern of the chewing cycle but can be considered as a shearing mechanism. (From Moses: "Studies in Articulation," J. PROS. DEN. 2:326, 1952.)

our carnivorous antecedents. The cusps of most carnivores are used for shearing and cutting. Human cusps, if unabraded, could be useful also for this purpose. Currently, a theory and practice is being promulgated which advocates steep cusps (in excess of fifty-five degrees). Presumably, this form is meant to be compatible with the pattern of the chewing cycle. It is important that it is being advocated

Fig. 11.

Fig. 12.

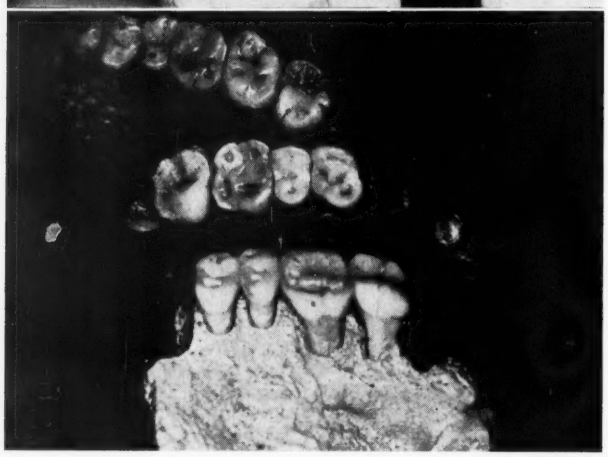

Fig. 11.—Teeth found in the Tabor Hill Indian burial ground show that wear usually occurs at the contact areas and forms a concavity in some instances. (Courtesy Royal Ontario Museum.)

Fig. 12.—Teeth from the Tabor Hill Indian burial ground show patterns of wear on both the occlusal and proximal surfaces. These teeth were so interlocked that they could not be lifted from the alveolar bone. Is this nature's method of splinting? (Courtesy Royal Ontario Museum.)

as normal for *complete mastication* and not for shearing purposes alone. I should like to emphasize that chewing is not shearing alone. A horizontal component may have to be introduced to permit chewing. Jankelson and associates[11] demonstrated the introduction of oscillating movements in the masticatory cycle, presumably to increase efficiency when masticating certain foods.

With natural teeth, because of the wear on the buccal cusps of the lower posterior teeth and the lingual cusps of the upper teeth, and because heavy func-

tion usually caused the maxillae to be wider than the mandible, until recent centuries in modern man, a steep occlusal pitch was developed. The inclination of the occlusal surfaces of the lower posterior teeth was directed toward the buccal and that of the upper teeth was directed toward the lingual. Thus, a shearing action was created as the occlusal surfaces of the mandibular teeth passed those of the maxillae. It combined very well with the triturating effect of the uneven, masticatory surfaces. Great chewing efficiency was established. The relative widths of the maxillae and mandible were of great importance as we shall point out. Modern man's mandible is usually relatively wider than the maxillae, quite the opposite to the architecture of the jaws up to recent centuries.

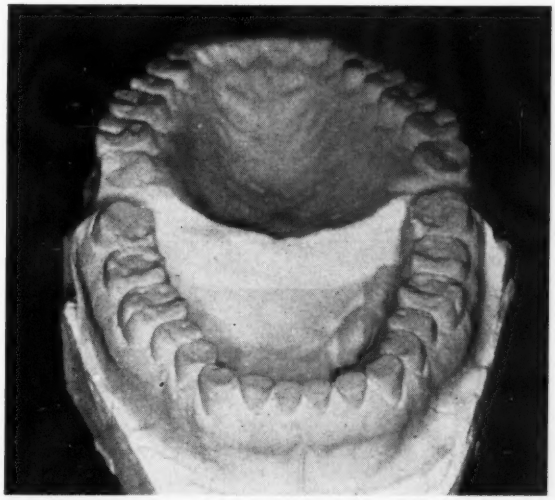

Fig. 13.—Casts of an Eskimo's teeth. Although the wear is still on the buccal side of the lower posterior teeth and the lingual side of the upper teeth, the resulting pitch is horizontal because of the relative widths of the related dental arches.

The reason that wear generally takes place on the lower buccal cusps and the upper lingual cusps is that they are the common contacting surfaces with their opposing teeth. The food elements between the opposing surfaces performs the attrition. This leaves a higher lingual edge of the lower posterior teeth as well as a longer buccal edge of the masticatory surfaces of the upper posterior teeth, virtually making a single shearing cusp of each tooth (Fig. 10). When the mandible travels in the chewing cycle, the sharper, higher lingual cusp embeds itself first into the bolus of food as does the upper buccal cusp from the opposite direction. The shearing action is thus created which, combined with the triturating effect, produces a very efficient masticatory machine. Anyone who has seen an Eskimo mascerate the toughest type of food imaginable can attest to this fact.

Gliding Movements, Bruxism.—Even though the chewing of food seems to be performed in a cyclic pattern, the fact that, under certain conditions, gliding does take place cannot be ignored, and if gliding does occur (and nearly everyone glides his mandible at some time or other), it must be recognized as a mandibular

movement. With well-worn cusps, interferences have been eliminated, as a rule, during gliding movements. Interfering cusps are a great factor in destroying related tissues particularly if the person suffers from bruxism.

Contact Points and Splinting.—Upon examining teeth of primitive people, it is nearly always evident that the contact points are not formed in the manner in which the student is taught from textbooks (Fig. 11). Frequently, there is much wear, and approximating teeth often not only contact but they seem to interlock. In fact, the wear on the proximal surfaces seems to produce an interlocking device of such a nature that the teeth almost appear to be splinted. It is difficult to remove teeth from the dried alveolar bony sockets of some skulls because the teeth are interlocked with their neighbors (Fig. 12).

Occlusal Pitch and Inclination.—While the wear on the occlusal surfaces of teeth is usually on the lower buccal and upper lingual cusps, the pitch is not always at the same angle. When the inclination of all of the lower posterior teeth is more to the lingual, the wear on the lower buccal cusp will cause the occlusal surface to be more nearly horizontal in pitch (Fig. 13). The result is similar on the upper posterior teeth where the lingual cusps wear more and the pitch becomes more nearly horizontal when the inclination of the tooth is to the buccal. Thus, the inclination of the tooth is a factor in the pitch of the tooth before wear takes place, while the wear itself is an additional factor in determining the pitch or inclination of the occlusal surface.

NATURAL ARRANGEMENT OF TEETH

About 1946, I uncovered a natural law about the inclination of natural teeth.[12,13] *"Under normal conditions a natural posterior tooth inclines in the direction of the ridge opposing it." The occlusal surface inclines toward the opposing contacting occlusal surface.* This law was found to hold true in all animals, from the mouse to the elephant, as well as in man. Let us examine some examples. In the beaver the mandible is broader than the maxillae, and the lower posterior teeth incline lingually and the upper posterior teeth incline buccally (Fig. 14). In the sheep and deer, however, the mandible is narrower than the maxillae, and the mandibular posterior teeth incline buccally. The maxillary teeth, of course, incline lingually (Fig. 15).

The law is strikingly illustrated by the inclination of the teeth of the bear. The mandible is narrower than the maxillae and the inclination of the teeth is outward, except in the third molar region. In this region the mandible is the broader and the third molar inclines inward (Fig. 16).

The maxillae of the bear exhibit a strange phenomenon but illustrate the point perfectly. The second molar is long and occludes with two lower molar teeth. The anterior half of the occlusal surface inclines lingually while the occlusal surface of the posterior half of the tooth (that part occluding with the last mandibular molar) inclines buccally (Fig. 17). The last mandibular molar is inclined lingually to face the posterior portion of the maxillary second molar.

The same law applies in man. Among primitive people the maxillae are seen frequently to be broader than the mandible except in the third molar region. Also,

the occlusal surfaces of the maxillary teeth incline lingually while the mandibular teeth incline buccally.

The reverse is usually the case with modern man. The mandible is usually wider than the maxillae. The result is that the mandibular bicuspids and first two molars are generally inclined lingually while the opposing maxillary teeth are inclined buccally. The third molars often incline more steeply than the others since the mandible is wider than the maxillae, especially in the third molar region (Fig. 18).

Fig. 14.

Fig. 15.

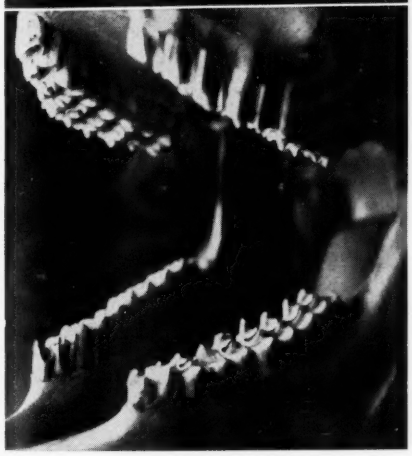

Fig. 16.

Fig. 17.

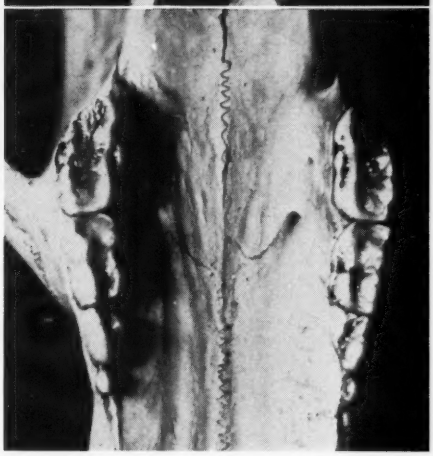

Fig. 14.—The mandibular teeth of the beaver incline lingually, and the mandible is broader than the maxillae.

Fig. 15.—The mandibles of sheep, deer, and most herbivorous animals, being narrower than the maxillae, result in the mandibular teeth inclining buccally. The maxillary teeth incline lingually.

Fig. 16.—The mandible of a bear. The last molar tooth inclines lingually while the others incline buccally. The mandible is wider than the maxillae in the third molar region while it is narrower anteriorly.

Fig. 17.—The last molar tooth of the maxillae of a bear is of great interest. The anterior half of the tooth inclines lingually while the posterior half, which occludes with the last mandibular molar, inclines buccally.

The law is strikingly confirmed in the human dentition by comparing the positions of the newly erupting posterior teeth with their positions later when growth is complete. When the lower first permanent molar erupts, it is near the ramus. The mandible is wider in that region and the tooth inclines lingually (Fig. 19).

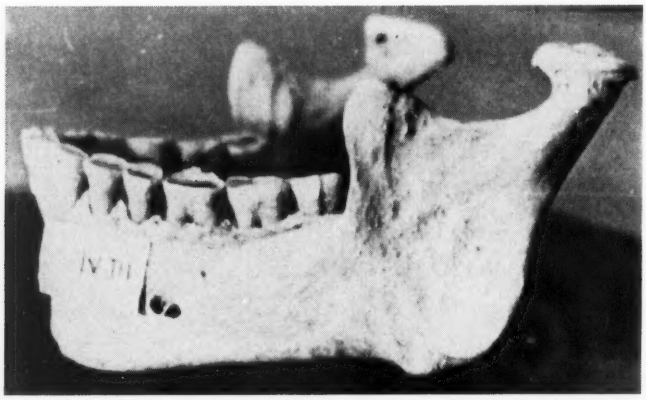

Fig. 18.—The mandible of an Australian aboriginal. Note the enamel knives and hollow food escape ways and the lingual inclination of the third molar. (From Moses: "Studies in Articulation," J. Pros. Den. 2:326, 1952.)

Fig. 19.—The first permanent molar of this Eskimo child inclines lingually. (Courtesy Dr. Arkle, Nanaimo, B.C.; from Moses: "Studies in Articulation," J. Pros. Den. 2:326, 1952.)

When the lower second permanent molar erupts, it occupies the widest position and inclines more lingually than does the first molar. The lower first molar now occupies a position where the mandible is relatively narrower, and the inclination is more to the buccal than that of the second molar (Fig. 20). Similarly, when

the third molar erupts, it inclines more lingually than the other two which have moved forward. The maxillary dental arch narrows in the region of the tuberosity, and the third molars usually incline buccally.

Thus, by studying nature, we learn that the inclination of posterior natural teeth will vary with the architecture of the bone and, therefore, with the position of the opposing teeth. The arrangement will differ with different individuals, and no set pattern is applicable for all persons. The inclination of the posterior teeth is never as uniform as is pictured in textbooks. The laws of inclination of teeth should be more widely recognized by orthodontists.

Fig. 20.—The second permanent molar inclines more to the lingual. (Courtesy Dr. Arkle.)

SUMMARY AND CONCLUSIONS

1. Wear has been present in human teeth for almost the entire period of human existence. The absence of wear has been manifested only comparatively recently.

2. The angle of wear conforms with the pattern of the chewing cycle when the maxillae are wider.

3. Efficiency is not lost with wear, but an efficient chewing mechanism is developed.

4. Several mechanisms have been evolved because of wear.

5. The inclination of a tooth and its unworn occlusal surface follows a natural law which is present in all animals.

6. The arrangement of teeth varies in each mouth in accordance with the architecture of the bone which governs the inclination of the teeth and should be recognized to a greater degree by orthodontists.

An attempt has been made to point out some natural laws in tooth form and arrangement and to demonstrate that some fallacious concepts have crept into dental thinking. Techniques naturally stem from concepts. It would seem to follow then that erroneous concepts should be corrected so that errors do not creep into our therapeutic efforts.

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DISCUSSION

Human Tooth Form and Arrangement From the Anthropologic Approach By Charles H. Moses, D.D.S., M.Sc.

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I HAVE READ WITH a great deal of interest Dr. Moses' article on the "Human Tooth Form and Arrangement From the Anthropologic Approach." I admire him for his scholarly research and masterly presentation of his anthropologic findings. I have not made such a thorough study of the teeth found in human and animal dentitions from prehistoric days as has Dr. Moses. I agree that the type of wear which Dr. Moses discusses will be found in most natural dentitions of individuals past middle life who have lived on coarse, fibrous, and abrasive foods. Similar conditions of wear are not uncommon in the dentitions of our patients. We can even find similar conditions of wear in some complete dentures made with the softer plastic teeth which wear more readily. I have seen a similar change in porcelain artificial tooth forms of dentures worn by tobacco or snuff addicts.

What I have found difficult to understand is his interpretation of this condition of wear as evidence of an evolution in the anatomic form of the human dentition, or that nature was endeavoring to perfect, or had perfected, a more ideally functioning dentition through these processes of wear.

I am quite sure that Dr. Moses has made no tests of the masticating efficiency of these mutilated dentitions that would justify this evaluation.

In function, the natural dentition is subject to the same conditions of wear when subjected to abrasive forces as is any other piece of machinery. The human dentition, although part of a living organism, has no unusual power or restorative ability to combat or overcome the natural laws of wear.

A slight degree of wear may improve the functional efficiency of most any mechanical device. Through an uncontrolled continuation of frictional wear, the mechanical device most often loses its functional efficiency. The natural dentition is not an exception to this law of frictional wear.

The convex-occlusal contours of the newly erupted tooth may present a more definitely interlocked occlusal relationship of the opposing teeth. This might be contrary to the smooth functional efficiency of the dentition. With the first preliminary stages of wear, the mandible is privileged a slight degree of eccentric

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mobility with a reduced strain upon the alveolar structure supporting the dentition. An excessive, uncontrolled continuation of this wear might wreck havoc to the functional efficiency of the human dentition, as would be the case with a lifeless piece of machinery.

The excessive degree of wear might more accurately evidence that, due to a human weakness, we have little more power to prevent or control such wear than does the inanimate piece of machinery, rather than that such structural changes were in any way evolutionary and nature's effort to perfect a more perfect masticating organism. I agree that we need a degree of freedom of mobility and smoothness in function between the maxillary and mandibular teeth in both centric and eccentric relations, and that closely locked intercuspations are undesirable in either the natural or artificial dentition. However, I do not see the propriety in advocating the worn-out machine as the ideal anatomic form of teeth.

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REQUIREMENTS OF ARTICULATORS FOR PROTRUSIVE MOVEMENTS

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IT HAS BEEN ESTABLISHED[1] that the mandibular movements are elliptical. To properly reproduce these movements, the elliptical principle must be preserved on the articulator with the different factors properly related to each other.

The guiding paths or paths of movement are fixed and immovable. Their relative position to each other is always the same for each individual. Therefore, to obtain the true paths of points placed between these two paths, we must reproduce these conditions faithfully.

The condyles and the lower incisors move from centric to protrusive position and produce the guiding paths. Mathematically, these paths are the abscissa and ordinate, and they are the primary paths.

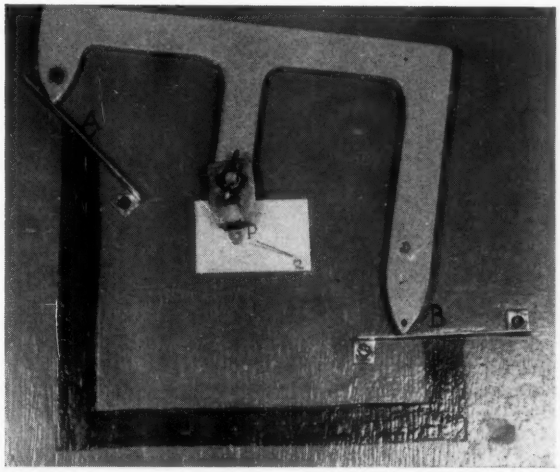

Fig. 1.—A model representing an articulator in the sagittal plane is used to trace pathways. *A*, The condylar guide. *B*, The incisal guide. The movable member may be used either as an upper or a lower member. When it is used as an upper member, the path is not the same as when it is used as a lower member.

The condyle and the incisors are the primary moving points. The tips of the cusps of posterior teeth are the secondary moving points. These secondary points move, guided by the primary points along the primary paths, and produce secondary paths in the upper posterior teeth that are in harmony with the primary paths. These secondary paths are the cusp inclines.

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UPPER MEMBER VERSUS LOWER MEMBER MOVEMENT

To study the protrusive movement, the articulator is represented schematically in the sagittal plane as shown in Fig. 1. In this figure two paths have been traced. These paths represent the movement of point *P*. The upper path represents the movement of point *P* when the lower member is used as the movable part to move

Fig. 2.

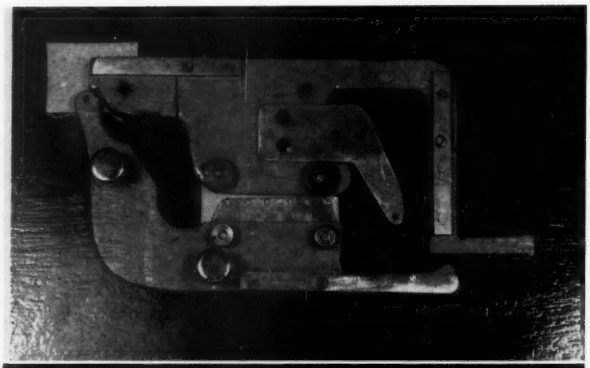

Fig. 3.

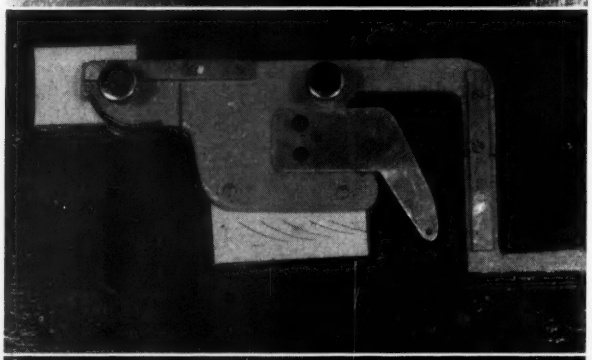

Fig. 4.

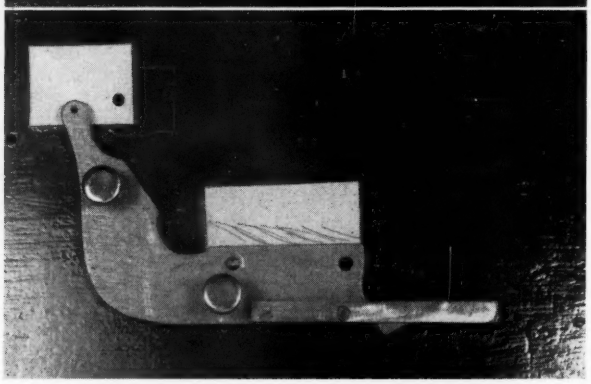

Fig. 2.—A model representing an articulator. The condylar guide is curved. Both guides are fixed to the upper member. The perforated plate fixed to the lower movable member is used to trace paths.

Fig. 3.—Paths were traced by moving the lower members forward in true imitation of nature.

Fig. 4.—The new paths are inverted when traced with the same elements with the exception that the upper member is moved backward.

point *P* to position *2*. The lower path was made when the upper member was used as the movable part, and point *P* was moved back from position *2* toward its original position. In both instances the movement was started from the same point that represented centric relation.

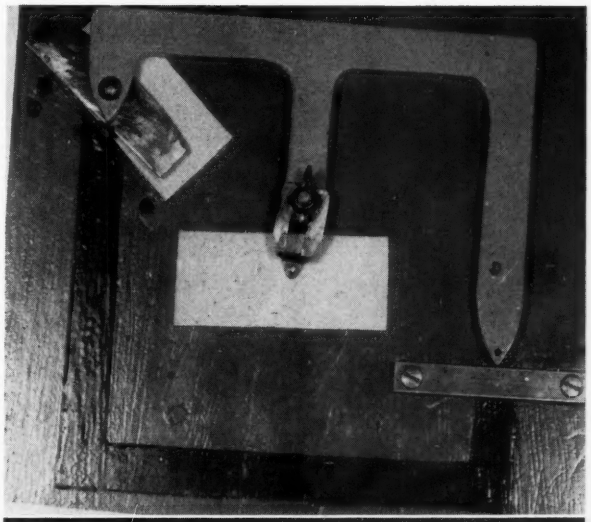

Fig. 5.

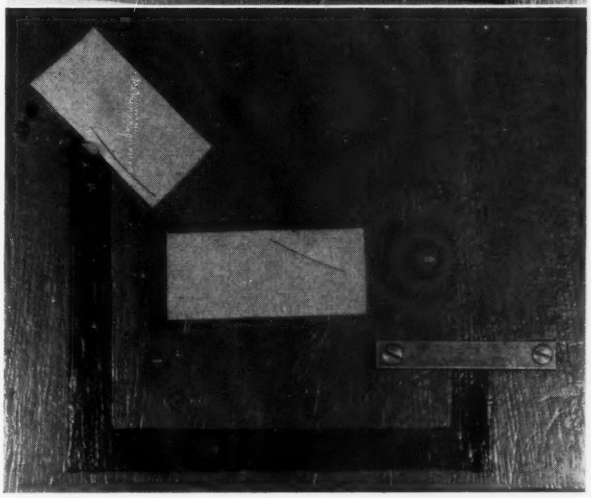

Fig. 6.

Fig. 5.—A model that represents an articulator with a straight condylar guide fixed to the upper movable member.

Fig. 6.—The condylar path traced when the upper movable member is curved.

We have been taught that this path would be the same. However, this demonstration proves that such is not the case. The full significance of this fact is shown when the condylar path is curved.

Another appliance representing an articulator is seen in Fig. 2. The condylar path is curved. The condylar and incisal guides are located in the upper member.

A perforated plate representing the tips of the lower cusps is fixed to the lower member. Protrusive paths were traced by moving the lower member forward in true imitation of mandibular movement (Fig. 3). The incisal guide was changed to the lower member and it was fixed in position. Then the upper member was moved backward to trace new paths as the movement is performed in some articulators (Fig. 4).

Fig. 7.

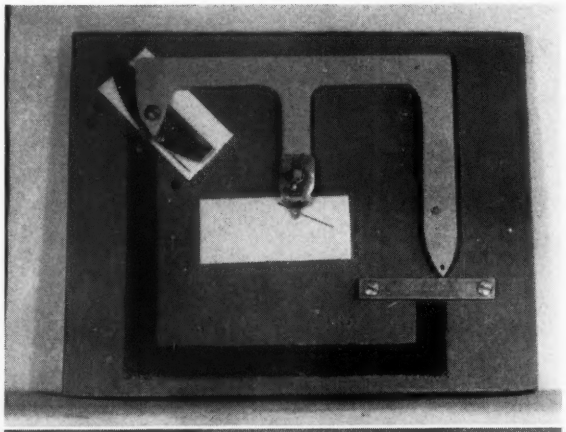

Fig. 8.

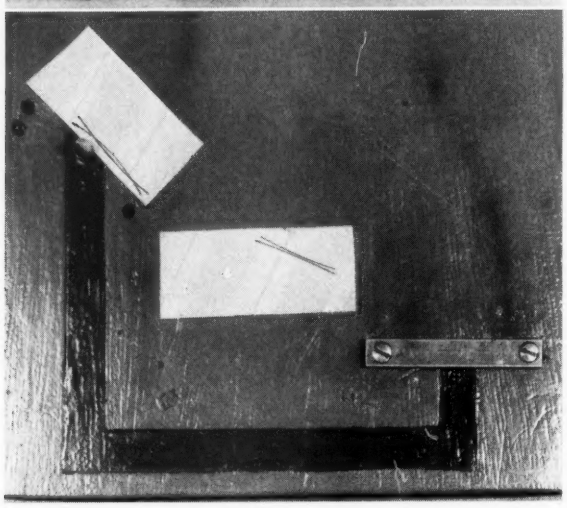

Fig. 7.—A curved condylar guide has been placed in position on the upper movable member.
Fig. 8.—The paths traced are curved in the opposite direction when a curved condylar guide is used on the upper member.

The elements with which these paths were traced are the same, but their relationship to each other has changed. For this reason, they produce an inverted path.

Some articulators have the condylar guide fixed to the upper member. This condition is illustrated in Fig. 5. In spite of the fact that the condylar guide is

straight, a path traced by the movement of the upper member in the condylar region produces a curved path (Fig. 6). This abnormal rotation influences the paths of the cusps.

One articulator has a condylar path which is slightly curved, and the instructions for using the instrument state that the object of this curvature is to simulate nature. Fig. 7 represents this condition. The paths traced are curved in the opposite direction (Fig. 8). The rotation of the upper member of the articulator inverts the effect of the curved condylar guide.

SUMMARY

The most important requirement in the reproduction of the protrusive movement on the articulator is to establish the inclination and curvature of the condylar path and its relation to the incisal path and the upper cast. The relationship between these three factors should not be altered at any time. This means that the condylar guide, the upper cast, and the incisal guide must be fixed to the upper member of the articulator because such is the condition in nature.

By means of this study, it has been possible to fix the requirements of the articulators in relation to the protrusive movements. The lateral movement will be studied in a subsequent article. The summary and conclusions will be made after this study has been presented.

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ACCURACY IN MEASURING FUNCTIONAL DIMENSIONS AND RELATIONS IN ORAL PROSTHESIS

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Ventura, Calif.

DENTISTRY HAS BUILT UP its science by two methods, namely, the technological and the logical. These two methods used in the conquest of sure knowledge are mutually interdependent. The technological may be regarded as the investigating hand and the logical method as the directing mind. If we depend entirely upon the technological, we may reach untenable empiric conclusions. If we depend exclusively upon reasoning, we may become falsely dialectic. What we probe by the hand, we must evaluate by reasoning and comparing. What we conclude by pure reasoning, we must retest by experiments of the hand. As we have gone forward in dentistry, we have increased the accuracy of our technology and the precision of our investigative instruments. At the same time, we have criticized more logically the ideas arising out of the experimental mazes.

Most natural scientists have been content to know how organs behave. Prosthodontists have had to know, not only how the oral organ behaves, but also all the processes of art necessary to make acceptable lifeless restorations. The prosthesis should be acceptable in function and tolerable to surrounding tissues. Restorative appliances that are made for the edentulous patient should be good looking, comfortable, and useful in performing a function.

In making esthetic and useful restorations for the edentulous patient, the dental articulator has its place. Students of prosthodontics have evidently considered this instrument important, for many of them gave it inventive devotion. Yet, most of the currently used articulators are incapable of reproducing a patient's mandibular movements.

PURPOSE OF THE ARTICULATOR

A dental articulator is not a chew-in device, nor is it a tooth-milling machine. It is not a mouth, nor is the patient. An articulator is first of all a diagnostic recording instrument capable of receiving and registering craniodental and maxillomandibular relations, the three dimensions of the oral organ, the axes of mandibular rotations, and the paths in which these axes travel in the various movements of the mandible. It should not only receive and register these relations, dimensions, axes and their paths of travel, but it should guide the dentist to incorporate the influence of these factors into whatever prosthesis is being built for a patient from whom the measurements were taken. In an articulator, we should be able to store all needed dimensional information, but we cannot endow it with brains so that it can

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compound our remedies automatically. The prosthodontist must be the master of this instrument of measurements and not trust it as if it were equipped with a brain. Furthermore, an articulator should be put together in such a way that it can be made to reproduce, without compromise, the border and habitual physiologic movements of the mandible.

There is some basis for the plaintive criticism that prosthodontists fail because they make the restorative remedies for a hard, rigid, lifeless articulator instead of for a patient. This criticism is no exaggeration if the articulator's relations between the mounted casts and the movable axes of rotation do not copy such relations of the patient. Nothing else could balk the efforts and aims of a prosthodontist more than an articulator which has false information stored in it.

There is a newer excuse for minimizing mechanics in the making of complete dentures. Some apologists state that the patient has tender oral membranes lying over pulsating blood vessels, variable tensed muscles operating the jaw, movable joints restrained by ligaments but postured by muscles, and alert outpost receptors in all these parts that gather information and "wire" it to the brain to direct the poses and movements of the mandible.

It seems to me that this tenderness, this variability, and this alertness of muscles and nerves of the oral organ would signify that we need to be more careful and accurate mechanically. The linings of the mouth will be covered by denture bases which will insulate their receptors from food contact and blunt the feeling capacity of the mouth. We dull the senses of the organ somewhat, thus interfering with its mechanics. The fact that the ridges resorb almost to relics in some patients cautions us to use greater care not to hurt their linings or to strangle their blood supply. The fact that many receptors are lost when the teeth are extracted emphasizes how much more we should respect the location receptors in the joints if we are to establish coordination of joints, muscles, and teeth. The fact that the organ of mastication is so well organized, when whole, by a communication and action system of nerves and muscles, denotes the demand for a restored unity in a mouth refitted by prostheses.

We can reach for this unity by making in our diagnostic studies the most accurate measurements of the most dependable dimensions of the oral organ. We can approach nearer this unity if we increase the accuracy of treatment to a level where every part of the mouth is satisfied in function. We want well-adapted denture bases, suitable interocclusal free-way space, centric relation, coordination of cusps and axes, and all those functional dimensions that add up to produce the most effective esthetics. All that has been learned by studying the oral neuromuscular system and the arterial supply to the linings of the mouth warns us to be more careful than ever in diagnosing and treating functional disorders. We treat functions best when we satisfy the positions required by the organs exercising them. We restore function by prostheses better when we position all of these factors and dimensionalize them so they can cooperate easily with the surrounding living remnants.

THE ARTICULATOR AND ANATOMY AND PHYSIOLOGY

An articulator should suit the anatomy and physiology of the oral organ. If it does, the inventor need not "make over" the human anatomy and physiology

to justify his contrivance. The following statements seem to be anatomic or physiologic facts:

1. The movements of the mandible, with reference to the maxillae, are accomplished by rotation about three gliding axes: (a) a horizontal intercondylar axis, (b) a right vertical condylar axis, and (c) a left vertical condylar axis.

2. The only isolable mandibular rotation movement capable of being seen is an opening-and-closing movement around the transverse intercondylar axis when it is rearmost in the head.

3. In lateral mandibular movement, the vertical condylar axis, around which lateral rotation occurs, is usually translated outwardly. It is tilted forward by the amount of jaw opening and inward by the amount of descent of the opposite advancing condyle beneath its eminence.

4. In ordinary mouth opening, the transverse condylar axis is translated forward and downward.

5. The translations of the axes are made by sliding actions in the discotemporal joints. The pure opening-and-closing rotation movements occur in the discomandibular joints.

6. The lateral rotations are slight movements. They are made by action in the upper part of the temporomandibular joint because the lower part of the joint is not a ball-and-socket articulation; it is a hinge.

7. The fore-and-aft movement of the jaw is a combination of axis rotation and axis translation. Maximum protrusion is produced by maximum translation plus minimum rotation. Wide mouth opening is produced by maximum translation plus maximum rotation.

JAW MOTIONS AND THE ARTICULATOR

It seems obvious that jaw motions at condyle levels can be resolved into glidable rotating axes. Observers, viewing the action of the condyles during chewing, either by roentgenograms or by watching joints exposed by surgery, are impressed more by the gliding actions than by the rotations. In most of the movements of the condyles, the glidings and the hinge actions cannot be isolated. Hence, in constructing an articulator, it should be made to reproduce the glidings as faithfully as the rotations. Most modern articulators could be made to reproduce simple opening-and-closing rotation but not any of the correct glidings.

If, in mounting the casts, we transfer to the articulator only the rearmost hinge relation without regard to the directions of the paths in which the hinge axis travels in the protrusive and lateral movements, we have made only a basic border mounting and have left out the most important functional recording, namely, the translative movements of the jaw (Fig. 1). It is just as important to record true dentohinge-axis relations in the protrusive and lateral positions as in the terminal position because the mandible opens and closes on this axis wherever it goes. We need to reproduce the line character and the slant of the paths in which the hinge axis travels. We should also be able to determine how far outward the rotating condyle travels in the lateral movement (Fig. 2). We have to obtain data from the patient's jaw movements which will aid us in locating the vertical condyle axes in the instrument. And, finally, we need to know the linear characteristics

of the Bennett paths and in which directions (other than outward) they may move the rotating vertical axes. The outward direction of a Bennett path may be combined simply with an upward, downward, forward, or a backward component. Its outward direction may also be united with combinations of these, such as downward and backward, up and backward, down and forward, or up and forward. A Bennett

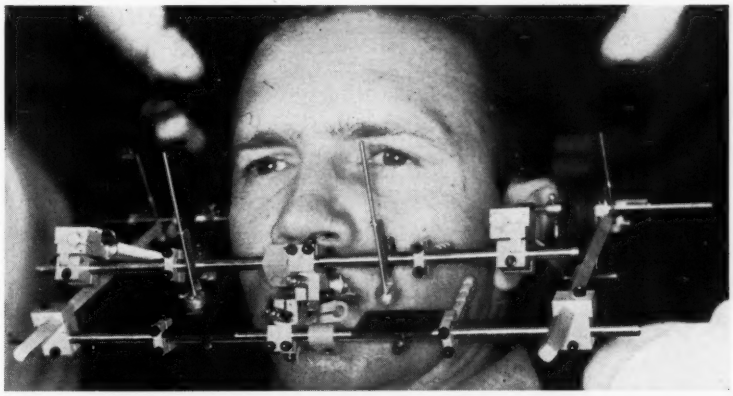


Fig. 1.—The mandibular movement recorder used to record the paths of mandibular movement.

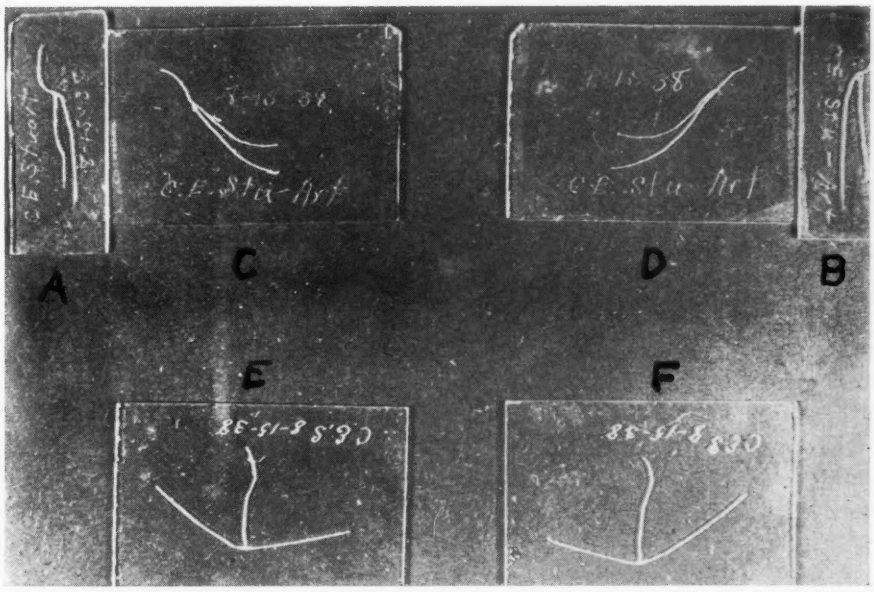


Fig. 2.—Tracings of mandibular movements. *A* and *B* are tracings of the sideshift or Bennett movement. *C* and *D* are tracings of condylar travel. *E* and *F* are Gothic arch tracings made in the horizontal plane.

movement may be very short or relatively quite long. It may take place at the beginning of the lateral movement, or it may be distributed throughout the lateral deflection. In other words, there is a definite timing in this side shift movement.

In studying the condylar movements experimentally and recording them in lines on glass plates, we learned how they remained constant in the individual but varied among individuals. As time passed, we learned how to use such lines to set an adaptable articulator to make it repeat the lines drawn by the patient. The outgrowth of the experimental equipment used in such studies was a mandibular movement recorder.

THE HINGE AXIS

From the beginning of these studies, we recognized the necessity of accurately locating the opening-and-closing axis by physiologic means (Fig. 3). The extensions of this condylar axis are permanently marked on the skin lateral to the con-

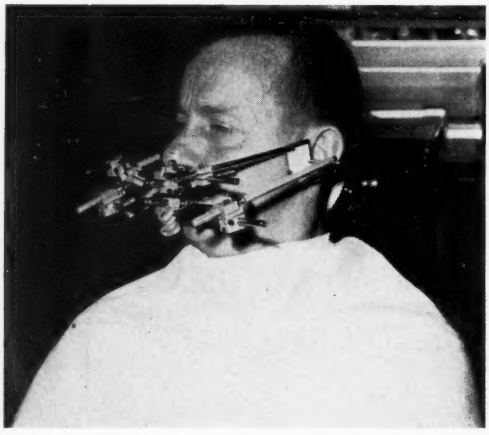


Fig. 3.—The hinge axis is located by attaching a fixed background to the maxillary teeth and an adjustable arm to the mandibular teeth. The axis is located by finding the stylus point location of simple rotation.

dyles by introducing tattoo pigment into the pigment layer of the skin. This permits repeated transfers of the dentoaxial relations of the patient to the articulator and allows us to satisfy a mechanical law which, in substance, states that to pantograph in three dimensions one axis must be duplicated.

To provide a means for orienting the casts of the mouth in the third dimension, the extension of a line from the hinge axis to the lower border of the orbit is extended to the right side of the nose and marked here with tattoo pigment.

THE MANDIBULAR MOVEMENT RECORDER

The mandibular movement recorder consists of two main parts: an upper and a lower three-piece face-bow. When in use on a patient, the bows are attached to the respective jaws through the media of a special pair of clutches cemented to the teeth (Fig. 4). The purpose of the upper bow is to hold vertical and horizontal recording plates in the condylar areas and to carry writing styluses on the anterior crossbar (Fig. 5). The inner surfaces of the vertical recording plates in

the condylar area carry hinge-and-axis indicating pins which are used to transfer the opening-and-closing axis of the patient to the articulator. The anterior crossbar also is equipped with a toggle for holding the orbital bow support which allows transference of the recorder to the articulator on the axis-orbital plane.

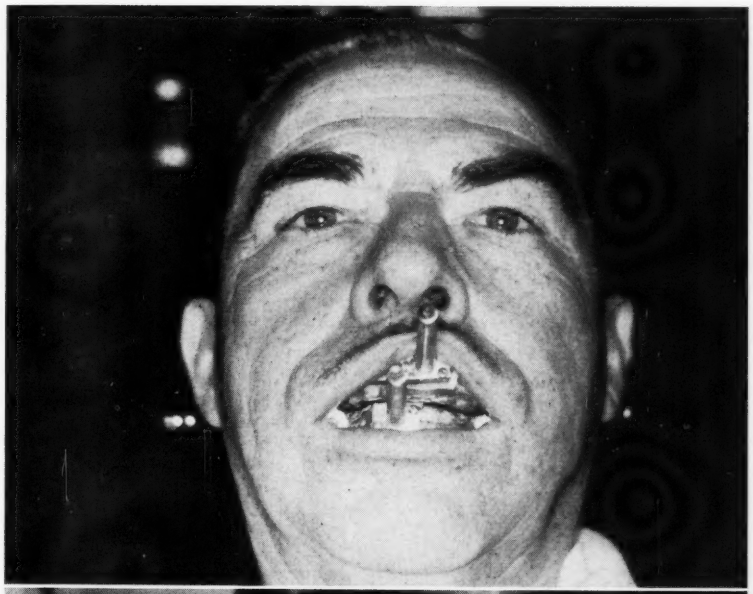


Fig. 4.

Fig. 5.

Fig. 4.—Clutches are cemented to the maxillary and mandibular teeth with separable studs attached. This provides firm anchorage to the respective jaws.

Fig. 5.—The mandibular movement recorder in position for making the tracings. Note the locations of the styluses and tracing plates.

The purpose of the mandibular bow is to carry vertical and horizontal styluses in the condylar areas and horizontally posed recording plates on the front crossbar. The horizontal condylar area styluses are set so that their tips are lying in, or

nearly so, the transverse hinge axis of the mandible when it is rearmost in the face. The horizontal styluses write the anteroposterior gliding effect of the opening-and-closing axis. The vertical condylar styluses are set at right angles to the horizontal condylar recording plates and used to record the sidewise or Bennett condyle movements. The anterior vertical styluses scribe Gothic arch tracings upon recording plates on the lower front crossbar. These vertical styluses are set perpendicular to recording plates, the plane of which is in line with the opening-and-closing axis in its rearmost position.

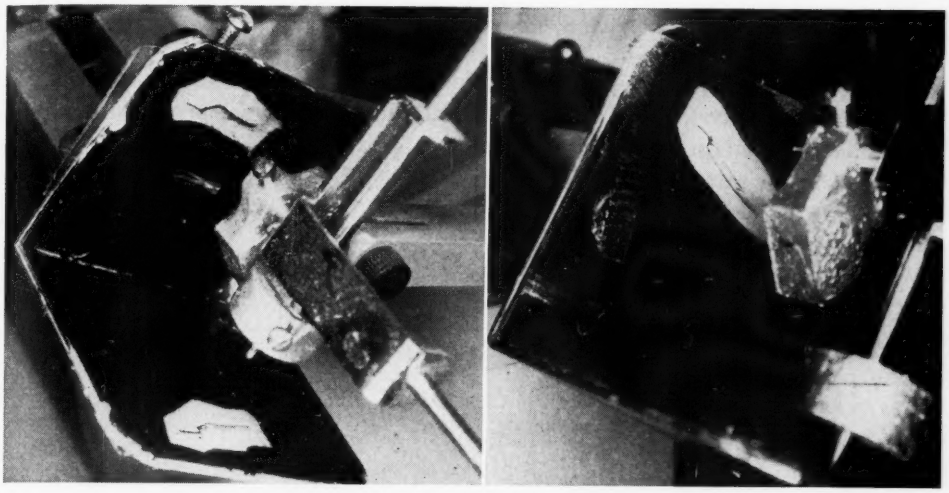
The recorder, therefore, has two styluses to write the Gothic arch tracings, two to write the effect of the anterior condylar glidings, and two to write the effects of the lateral condylar glidings. We school ourselves and the patient to make the instrument record the border positions and movements for two reasons: (1) They are constant enough in positions, directions, and path characters to be dependable (Fig. 6). The border movements are used because in such a simple movement as straight protrusion the patient seldom can make the same movement twice. The so-called habitual positions and movements vary according to postures, health, muscular and nervous states. Muscles do seem to have memories but not very accurate ones. (2) These border movements have fidelity and can be recorded repeatedly. When transferred to an articulator, they become boundary positions and movements on the machine. When the true boundary movements are recorded and transferred, all other movements are automatically included in the circumscribed areas of movements. Oral remedies, built so that the patient can reach the border movements, condition the jaw for a freedom that it would not have if the restorations were built upon habitual movements that are treated on the articulator as if they were boundary movements.

In the technique of jaw-movement recordings, however, we do use a single protrusive line representing the patient's attempt to protrude the condyles symmetrically. No attempt is made to repeat it, for this movement is directed solely by muscular control. The patient cannot be taught to repeat a given protrusive movement pattern.

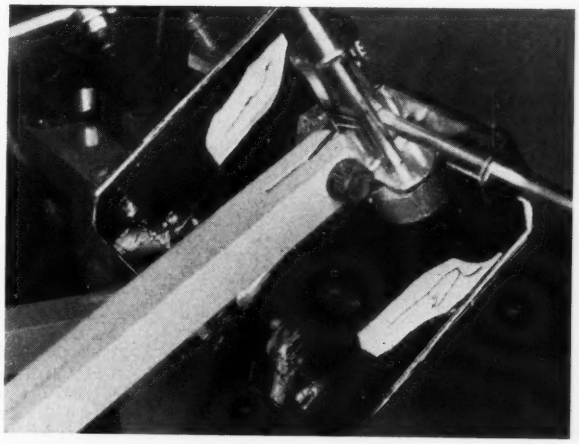
CONDYLE PATH TRACINGS

The tracings of the condyle paths are *effects* of the true paths, not the paths themselves. They are outside the face at some distance from the axes of the joints. They are longer than the paths to which they correspond. In other words, they are magnified records. The procedure of using magnified records and then reducing them to original values is used throughout science and industry to improve accuracy. The condyle tracings are each made up of two parts: one is a forwardly drawn tracing, and the other is a backward tracing. The point or dot between the two parts of this line is at the position of the centric relation as indicated by the stylus. Likewise, the lateral tracings are not true Bennett paths, but they represent

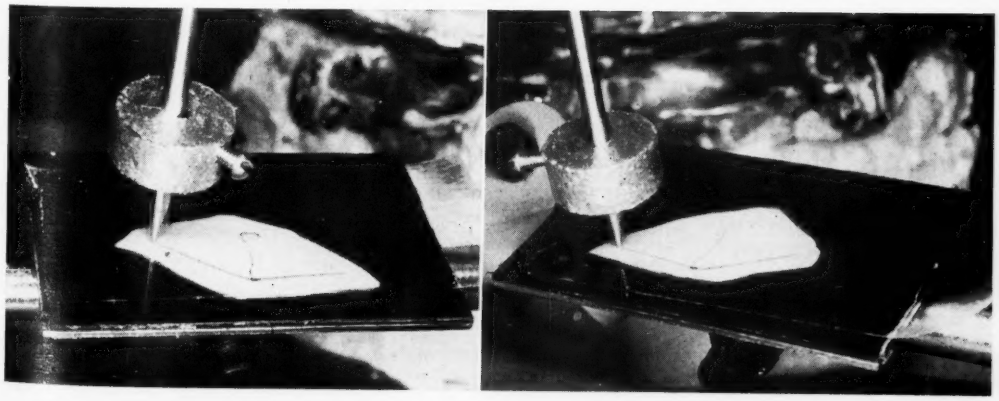
Fig. 6.—Typical condylar tracings. *A*, Note the character of forward condylar travel recorded in the upper tracing. *B*, Note the difference between the lateral and protrusive paths. The upper line is the protrusive path. *C*, Note the lateral movement of the condyle in the lower tracing. *D* and *E*, Gothic arch tracings in the horizontal plane. The lines extending backward were made by protrusive movement. The lines extending medially and laterally are border paths made by lateral movement.



A. *B.*



C.



D. *E.*

Fig. 6.—*For legend, see facing page.*

their effects projected at some distances away from the joints. Each tracing is made up two parts joined at the point of centric relation as indicated by the stylus. The two Gothic arch tracings have in them the *effects* of the lateral and anterior movements of the condyles. They are also influenced by any opening and closing of the mandible that might occur. If drawn at a given level, they are the resultant lines of condylar rotations and slidings.

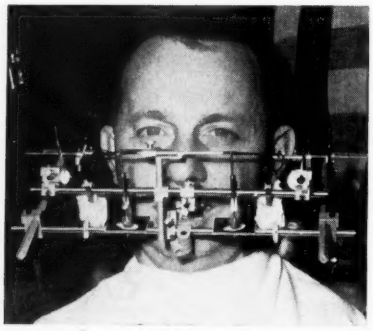


Fig. 7.—The bows of the recorder are cemented together. The orbital bow has been placed preparatory to removing the assemblage from the patient.

Good use is made of the reverse tracing of each condylar-area line. The reverse tracing of each anterior condyle line serves as an index of the upward or downward path direction of the outward rotating condyle. The reverse tracing of the Bennett line is an index of the backward or forward path direction of the outward moving rotating condyle. The reverse tracing of the anteroposterior condyle path discloses the action of the rotating condyle vertically. The reverse tracing of the Bennett line discloses the action of the same in a horizontal plane. It would be difficult to incline the controls on the articulator if we depended solely upon the Gothic arch tracings. Furthermore, it has been shown that an articulator cannot be set as accurately by relying upon a single Gothic arch tracing as upon two. The accuracy of setting can be increased by using the Bennett tracings to countercheck the Gothic arch tracings.

MAGNETIC STYLUSES

The lines are written by frictionless ball-point styluses that are magnetically controlled. They run easily over the enameled smooth plates that have been covered with a fine chalk powder deposited there by desiccating it from an alcoholic suspension. The tracings are preserved by covering them with adhesive cellophane.* The styluses can move smoothly over the protective cellophane covering. Friction, once a source of error when styluses plowed through wax coatings, has been eliminated, and it is also absent when the recordings are used to set the articulator.

After the record lines are made and covered, the upper and lower face-bows are cemented firmly together in centric relation by quick-setting stone so that they

*Scotch tape.

become one mechanical piece (Fig. 7). The axis-orbital indicator is placed so that it records the location of a chosen craniofacial plane. This being done, the immobilized recorder becomes a static transferring device and, as such, can be used to take from the face and transfer to the articulator the following records: the dentocranial relation, the maxillomandibular centric relation, the posterior hinge position, and convenient sagittal relations.

TRANSFER OF JAW RELATIONS

To accomplish the transfer, the face-bows are unscrewed from their respective clutches, and the whole assemblage is withdrawn from the face as a unit. To remove the clutches from the teeth, each clutch is separated into its parts by unscrewing the anterior part from the body of the tray. The parts are then reassembled,

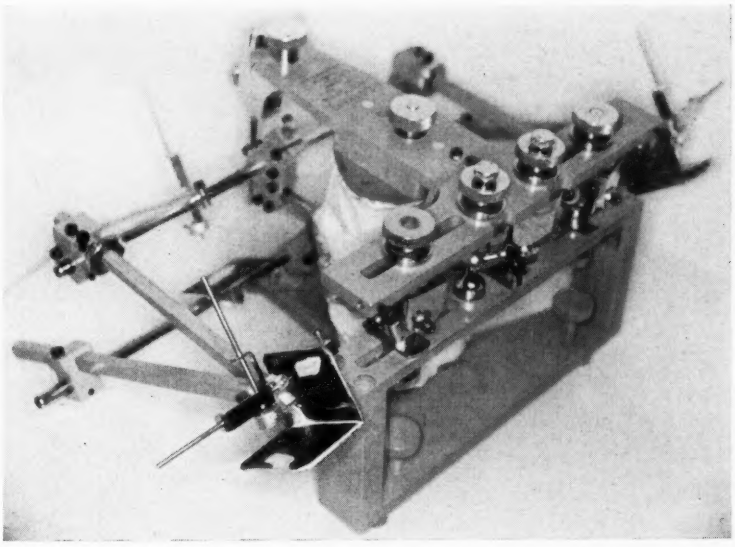


Fig. 8.—The recorder is attached to the articulator, and the lines of travel produced by the patient are duplicated by the adjustment of the articulator.

washed, filled with stone, and attached firmly to their respective face-bows. The assemblage, with the casts attached, is then carried to the articulator for mounting. The axis indicator styluses of the recorder are set so that their points are in line with the axis-slide brackets of the articulator. The axis-slide brackets are moved out so that they are equally placed on each side, i.e., the same number of calibrations and their points are aligned with the recorder axis indicator styluses. The upper arm of the articulator is attached to the upper cast first so that it is related to the chosen craniofacial plane. Subsequently, the anterior stop pin is inserted and set to maintain the proper vertical opening. The lower cast is then attached to the lower arm of the articulator. Finally, the stone cementing the two face-bows together is removed (Fig. 8).

THE ARTICULATOR

The recorded lines are used to set the articulator. Here, it will be advantageous to describe the instrument briefly and enunciate some of the principles followed in contriving it (Fig. 9). The articulator consists of two main frames, an upper and a lower. The upper frame is centered on the lower and maintained in centric

Fig. 9.

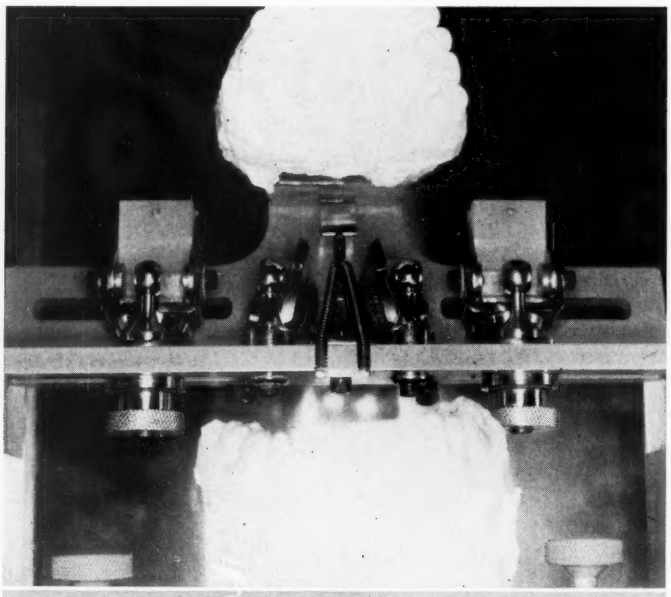


Fig. 10.

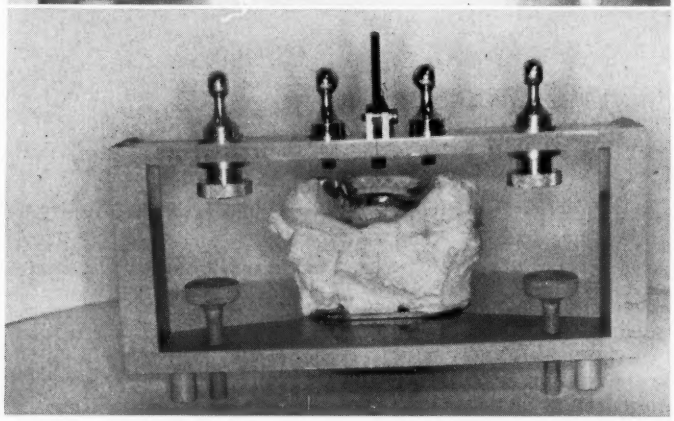
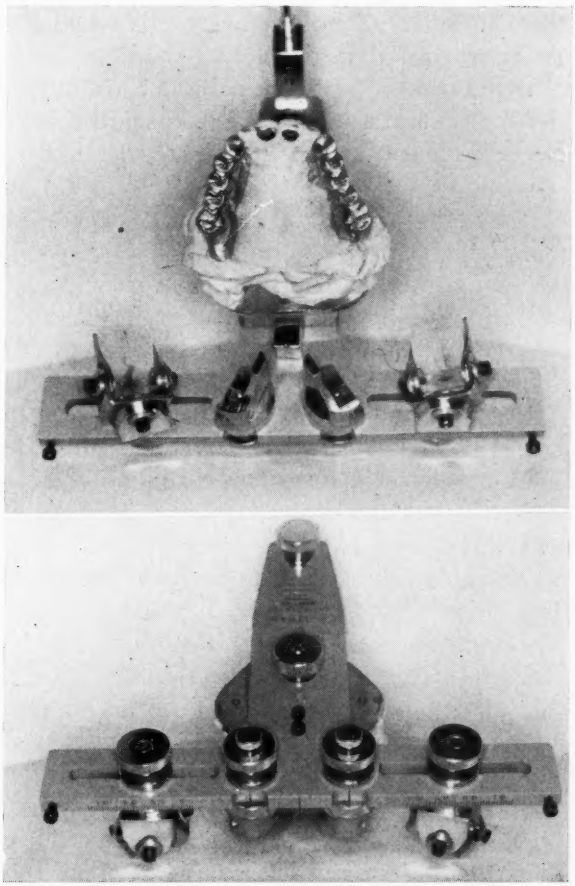


Fig. 9.—The articulator is opened to show the mandibular mechanical condyles and cranial guides.

Fig. 10.—The mandibular part of the articulator illustrating the arrangement of the mechanical condyles.

relation by a spring-loaded arm engaging a groove. The upper frame carries all of the cams that direct the gliding of the condyle mechanisms, namely, the right and left guides for the sideshifts (the Bennett movements) and the right and left fossa cups which carry the eminentias under which the condyles glide.

The lower frame of the articulator carries the mechanical condyles and simulates the mandible. The mechanical condyles are truncated spheres through the centers of which passes the opening-and-closing rotation axis. The vertical axis of each rotating mechanical condyle (outer) passes through the spheres at right angles to the transverse axis. The cams, or guide controls of the mechanical condyles, when set, remain fixed in relation to the upper teeth and dental arch. The mechanical condyles and their axes remain fixed in relation to the lower teeth. These conditions duplicate the anatomic relationships of the jaws.



A.

B.

Fig. 11.—The maxillary part of the articulator. *A*, The gliding surfaces of the cam guides on the lathe bed. The inner cams are the Bennett movement guides. The outer cams are the mechanical eminences. *B*, Top view of the adjustments for the position of the cam guides.

To simplify the construction of the articulator without changing or violating any principles, the split mechanical condyles are placed on the lower frame (Fig. 10). The outer half of the mechanical condyles traverse the under surfaces of the mechanical eminences and travel in the fossa cups laterally when rotating for lateral mandibular movement. The inner half of the mechanical condyles engage the adjustable cams that guide the sideshift movement of the lower frame.

The outer half of the mechanical condyles can be adjusted by sliding them in or out in a lathe bed as the data derived from the patient by means of the mandibular movement recorder indicates the position of the vertical rotation axes. The inner half of the mechanical condyles remains fixed and has the sole purpose of engaging the sideshift cams fastened to the maxillary frame.

The fossa cups into which the mechanical condyles are received also can be adjusted in or out in a lathe bed to equal the position of the mechanical condyles (Fig. 11). When the mechanical condyles are in centric position or are acting as the rotating condyles, they are tangential to the superior and posterior surfaces of the fossae and to the eminentias. The fossa likeness is so cradled that it can (1) be turned clockwise or reversely horizontally, (2) be tilted down or up laterally to provide vertical adjustment or to be maintained horizontally, and (3) be slanted anteriorly to give the eminentia path of the mechanical condyle the desired inclination. Each of these adjustments can be made by regulating the proper screw control.

The sideshift or Bennett cams are adjusted by turning them against the inner half of the mechanical condyles. If the original blanks do not permit the proper Bennett movement and timing, they may be altered by grinding. The eminence blanks are made of plastic in nine geometric radii from 3/8 inch up to 1 inch, in 1/8 inch steps. Also, one has a radius of 2 inches, another has one of 4 inches, and another one is straight (Fig. 12). They are interchangeable. They may be ground, or plastic material may be added to obtain the proper anatomic contour or curvature. Often the protrusive eminentia line differs from the lateral path. In such cases, it is simple to make the plastic eminence so that it will exactly imitate the patient's articular eminence in its functional direction (Fig. 13).

In most articulators, the upper and lower parts are held together by a bar passing through a condyle path guide (Fig. 14). In such an articulator, it is impossible to observe how disharmoniously arranged teeth can make the condyle dip below the eminence during closures. The temporomandibular joint is neither a pressure nor a tension joint. Any incongruity of the teeth with the joint may cause either undue pressure or tension in the capsular ligament.

The operating parts of this instrument are devoid of set screws because such means have a tendency to malalign parts. All parts are held together by radial tightening.

In axle-ball condylar construction common to most articulators, four clearances must be provided that add up to several thousandths of an inch discrepancy. In this instrument, the condyle-ball surface bears directly against the mechanical fossa and plastic eminentia.

ADJUSTMENT AND MOUNTING RECORDS

After the articulator has been set so that it will make the mandibular recorder repeat the movements which the patient made, the calibrations are recorded on a card especially printed to assist the dentist to make all the necessary observations and write them in place (Fig. 15). When the dentist is sure that he has the instrument set and the calibrations preserved in his records, he may remove the

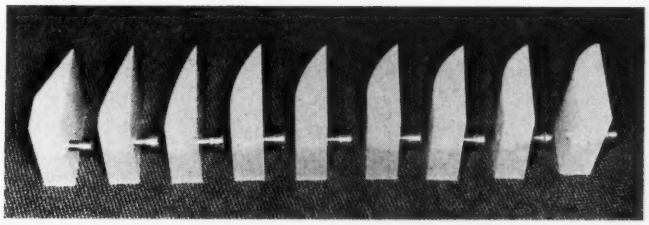


Fig. 12.—Eminentia blanks are made with different geometric configurations. These may be altered by grinding or additions may be made to them in plastic.

Fig. 13.

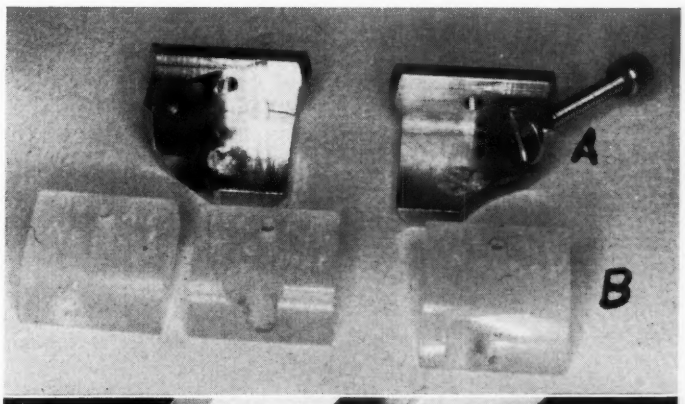


Fig. 14.

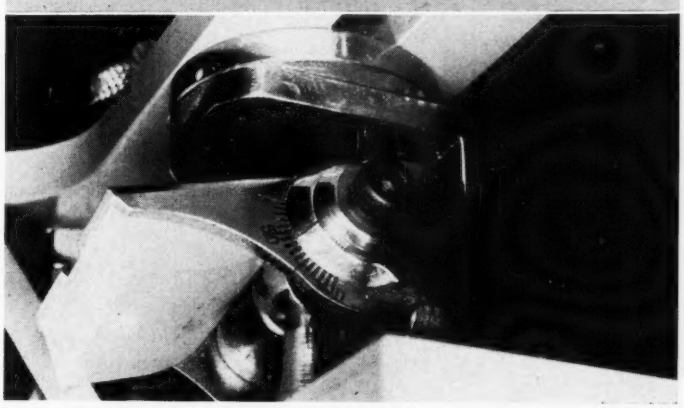


Fig. 13.—*A*, Metal sideshift cams have been ground to give the proper timing of the Bennett movement with the forward travel of the condyle under the eminentia. *B*, Plastic eminentias which have had plastic added and have been ground to make the articulator movements coincide with those of the patient.

Fig. 14.—The apposition of the mechanical condyle ball with the fossa and plastic eminence. Note the absence of an axle bar.

clutches, casts, and cast attachments from the arms of the articulator. Then, by means of a simple axis-orbital caliper or transfer bow (Fig. 16), he may return to the patient and, from the axis-orbital tattoo marks, obtain the data necessary to attach the upper cast of the patient's mouth to the maxillary frame just as he

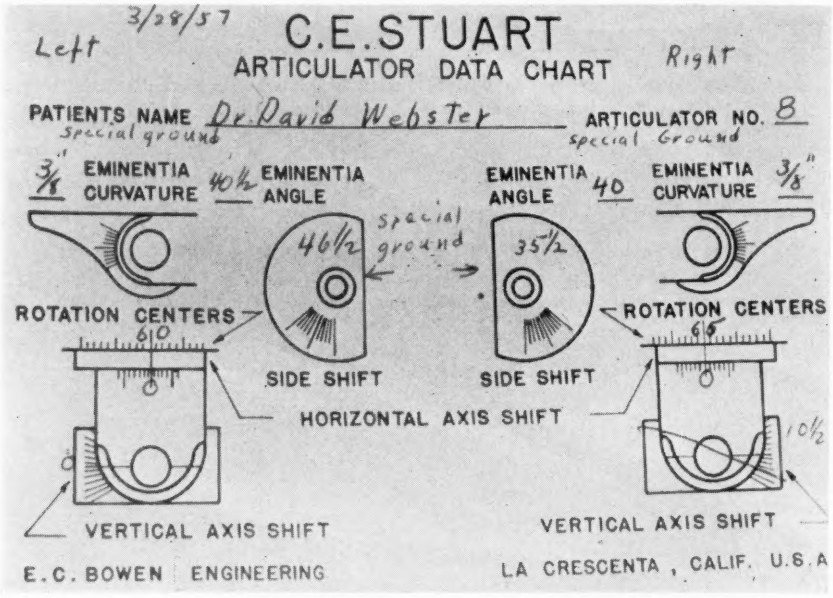


Fig. 15.—The card used to record the articulator settings.

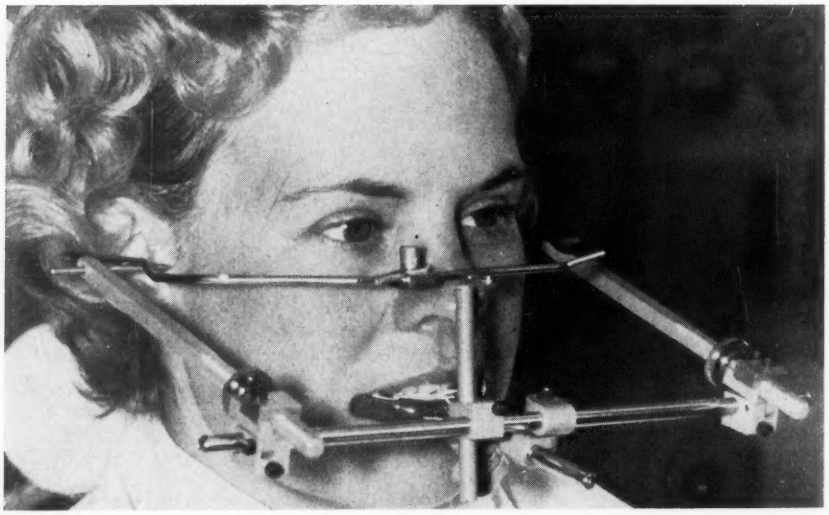


Fig. 16.—The face-bow transfer used to orient the upper cast on the articulator on the hinge axis and the axis-orbital plane of the patient.

previously attached the cast in the clutch (Fig. 17). After the upper cast has been attached, the lower cast is related by means of a centric interocclusal record (centric checkbite). When the lower attachment plaster is set, the interocclusal

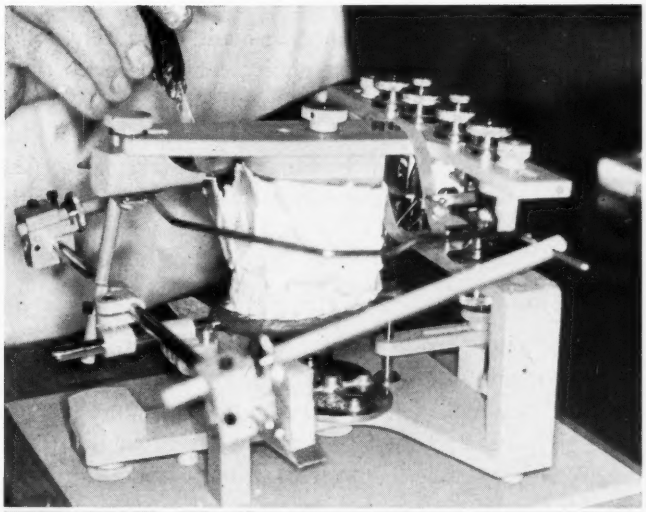


Fig. 17.

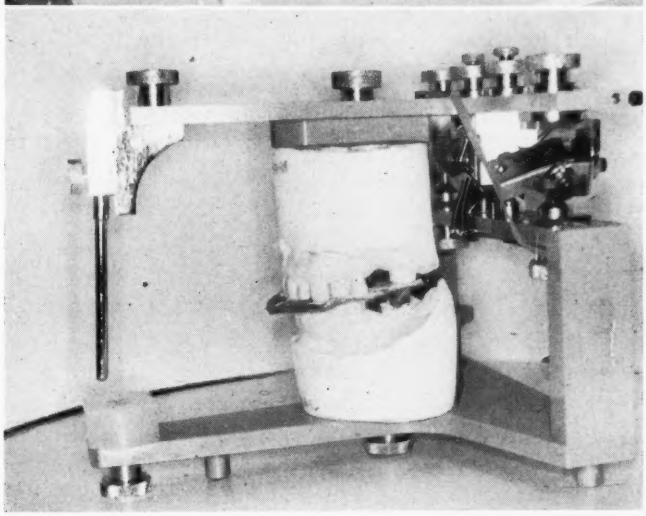


Fig. 18.

Fig. 17.—The upper cast is mounted on the articulator duplicating the hinge-axis of the patient and locating the upper cast with the proper reference to the axis-orbital plane.

Fig. 18.—The casts are mounted on the articulator which duplicates the habitual and border movements of the patient's mandible.

recorder may be removed from the articulator and the anterior stem disengaged so that the casts can seek their occlusal centric position and all habitual and boundary positions (Fig. 18).

We have found it advisable to use great care in making the centric interocclusal record. Most so-called "checkbites" are "snap" taken as if it were easy to make such records. We have tried plaster, modeling compound, various kinds of wax in various plies, or wax plied about metallic foils, and quick-cold-curing plastics. It has been harder to find a suitable method and material for making such a record than anything else that we have tried to do. Long ago we were aware that so-called lateral occlusal records could not be made accurately. The recorded lines obtained from the patient constitute the equivalent of a series of progressive interocclusal records that show what the maxillomandibular relations are from the far lateral all the way to the centric position. If a centric interocclusal record is not correct, the lateral interocclusal record would be incorrect also. Interocclusal recorders are not accurate unless they are faithful throughout the entire path of mandibular travel.

CONCLUSION

The instruments and their adjustments may seem complicated to the uninitiated, the lethargic, and the "short cutter." But to the real student, this accurate method of studying mandibular movements becomes a fascinating game. It consists of a complexity of very simple plane and solid geometric problems which can be readily solved. Furthermore, it is impossible to progress in our learning unless we master and understand the most constant parts of the masticatory system and the temporomandibular joint which constitutes two moving feet of the tripod-like organ of chewing.

I appreciate the assistance of Dr. Harvey Stallard of San Diego for his help in the preparation of this article.

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DISCUSSION

Accuracy in Measuring Functional Dimensions and Relations in Oral Prosthesis by Charles E. Stuart, D.D.S.

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DR. STUART HAS SET the background for the description of his instruments by calling attention to two approaches to the problems involved in jaw relations, articulators, and the method of transfer of jaw relations to the articulators. He recognizes the deficiences of both the arm chair scientific approach and the experimental approach. However, it appears that a *combination* of these two approaches must be combined with an adequate knowledge of the basic sciences that may be involved. Without positive and accurate knowledge of these basic sciences, either or both of the possible approaches may be slanted to fit the desires of the individual investigator. Arm-chair science can be accurate only if the arm-chair scientist has an adequate background of both the involved basic sciences and experimental information. Any discussor is almost always in the class of the arm-chair scientist if he has not worked with the instruments in question. I am in that position, *except* that I have seen the instruments and have studied the blueprints of them.

I am pleased to note that Dr. Stuart recognizes certain limitations to the capacities of articulators. Regardless of the instruments used, the dentist must not only know their limitations, but he must also know what can be done about the effects of these limitations.

Dr. Stuart specifies that an articulator should be able to reproduce, without compromise, the border and habitual physiologic movements of the mandible. Obviously, this condition is not met completely by the instruments that are adjusted entirely by means of interocclusal records. Any instrument that is adjusted solely by a series of these records can be absolutely correct only in the exact positions at which the records were made. There may be question, however, that the *absolute reproduction of all habitual* physiologic movements is necessary. Certainly, any movements made by the patient *when the teeth are out of contact* are of no importance to the arrangement of teeth. Likewise, it is desirable to have any movements that *may* be made while the teeth are in contact reproduced on the articulator. This is necessary so the occluding surfaces of the teeth can be shaped to be in harmony with each other in any position in which they may come in contact. In order that this harmony can be maintained during function in the mouth, the

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articulator should approximate those movements of the mandible that *may* occur when the teeth are in contact. This involves: (1) the correct relation of the two casts to the opening axis of the instrument, (2) the establishment of the correct centric relation, and (3) the development of guiding surfaces in the mechanical counterparts of the temporomandibular joints so the casts may assume the same relations to each other that the denture foundations have to each other in the mouth while the teeth are in contact.

Dr. Stuart has shown us ingenious instruments which he designed to accomplish these desirable results. At first sight, they may appear to be quite complicated, and yet when they are examined carefully, they are not too complicated to be practical.

The mandibular movement recorder is a kinematic face-bow with tracing plates and styluses placed in strategic positions for recording the movements of various parts of the mandible as they are "extended" to reach the tracing devices. The tracings made opposite the condyles are *"extensions"* of the condyle so their movement can be observed. The Gothic arch (needle-point) tracings on the anterior cross bar are *"extensions"* of the movement of the body of the mandible. It is significant that only *border* movement registrations are used in the adjustment of the articulator.

The orientation of the face-bow and the cast to the arbitrary facial or cranial landmarks seems to be unnecessary, *except* for the convenience of *observing* the anterior teeth and the occlusal curvature on the articulator as they will be orientated in the mouth. All of the tracings are relative to each other, and so long as this relationship is maintained, the vertical orientation of the cast to the axis of the instrument is unimportant, except for convenience. This is provided, of course, that the articulator is adjusted to conform to these records. The directions taken by the various styluses should not be permitted to be confused with the directions of the actual movement of the mandible itself. A posterior movement by the working-side condyle is likely to be developed largely by the fact that the tracing is made as an extension of the horizontal axis of the mandible.

The use of magnetically controlled ball-point styluses appears to be a fine method for overcoming one problem of tracings. However, there is a possibility of the weight of the recording apparatus altering the normal position and movements of the mandible, but this would be difficult to demonstrate or to prove.

One other important consideration is that the clutches must be cemented to the teeth during the making of the registrations. This is impossible for the construction of complete dentures, and the resiliency of the supporting tissues would be likely to produce errors in the registrations when the recording apparatus is used for making complete dentures.

The articulator itself is obviously a very fine instrument which can be adjusted to move in accordance with all the various tracings made on the transfer apparatus. It has movements controlling elements which are individually adjustable and which may be modified further for the reproduction of detailed irregularities of movement which may have been recorded.

It has a variable intercondylar distance which overcomes one of the major deficiencies of most articulators. Its machining and adjustment mechanisms allow for accuracy in its adjustment.

The horizontal condylar guidances are not locked in a slot, so the effect of occlusal disharmonies can be observed by noting that these guidances do not remain in contact. This certainly is an advantage which is most apparent for making diagnoses before treatment and for perfecting balanced occlusion.

The mounting of the casts in centric relation (the posterior terminal-hinge position) is done by means of an interocclusal record. I am happy to note that Dr. Stuart emphasizes the fact that if this record is incorrect, all of the other articulator adjustments also will be incorrect. There is an interrelation between these relationships.

Dr. Stuart is to be complimented on the development of the ingenious devices which can accomplish his objective, provided the dentist uses them with understanding and judgment. Any questions I have raised are pointed out with the objective of stimulating further thought and research along these lines and not to depreciate the value of what he has shown.

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A CLASSIFICATION OF REMOVABLE PARTIAL DENTURES BASED UPON THE PRINCIPLES OF ANATOMY AND PHYSIOLOGY

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THIS CLASSIFICATION IS BASED upon the relations of the anatomic and physiologic factors of the maxillary and mandibular dental arches. The more ideally we relate the factors of the abutment teeth, or the remaining teeth, to the alveolar supporting bone, the greater the physiologic values will be.

The principles of anatomy and physiology are the basic principles involved in all partial dentures. Therefore, it seems reasonable that a classification based upon these factors will be most logical. Likewise, these principles are the governing ones in design, types of clasps, connectors, broken stress attachments, impression methods, types of teeth used in restoration, and in the correction of the occlusions.

Many removable partial denture classifications have been based upon the numerical number of teeth remaining or those that have been lost. Such classifications were exemplified by the work of Cummer.[1] He showed that there are 131,072 different possible combinations of partial dentures when both the maxillary and mandibular dental arches and a full complement of thirty-two teeth are considered. As you can see, the potentiality of numerical values runs rather high; therefore, this classification is based upon the relationships of the abutment teeth to the supporting residual alveolar ridge.

A logical working classification is thus developed which is expressive both to the dentist from a physiologic standpoint and to the laboratory technician from a technical standpoint. The total value of any partial denture is based upon the coordination of the abutment teeth and the alveolar ridge support to the maximum degree. Therefore, a classification should be based upon the morphology and physiology of each dental arch. These factors, in turn, should be the guiding values as to the design and the arrangement of the various connectors to be related to the alveolar ridge support. Such a classification would be very beneficial in determining the particular type of connector to be used, and in determining the correlation required in selecting the type of broken stress as applied to that relationship of function between the abutment teeth and the supporting alveolar ridge.

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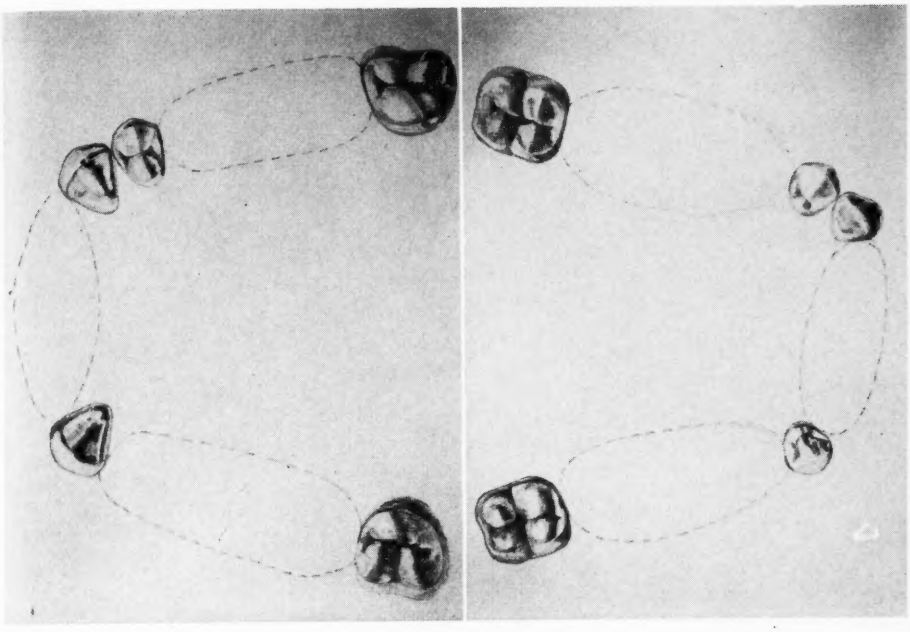


Fig. 1B.—Class I.

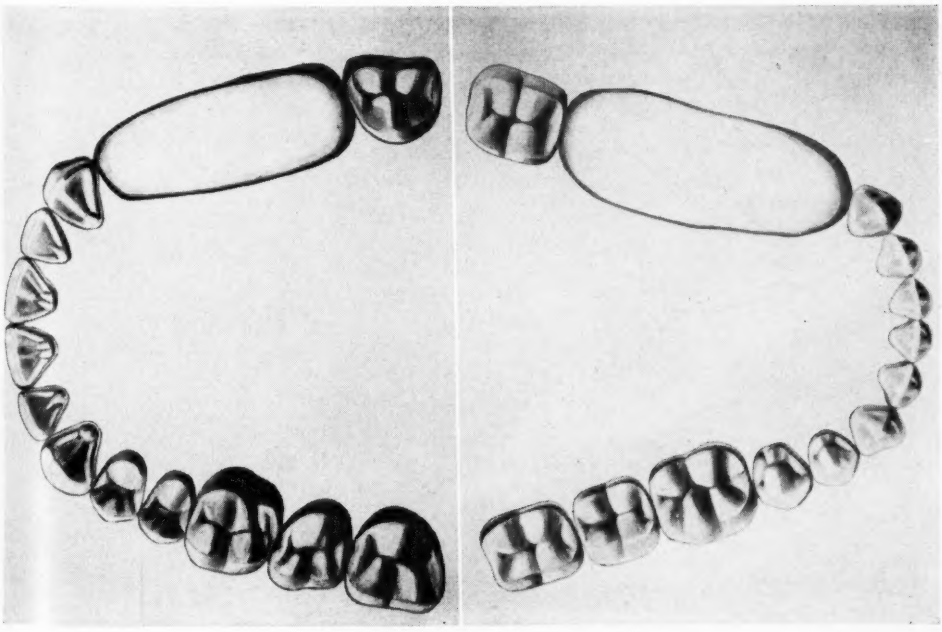
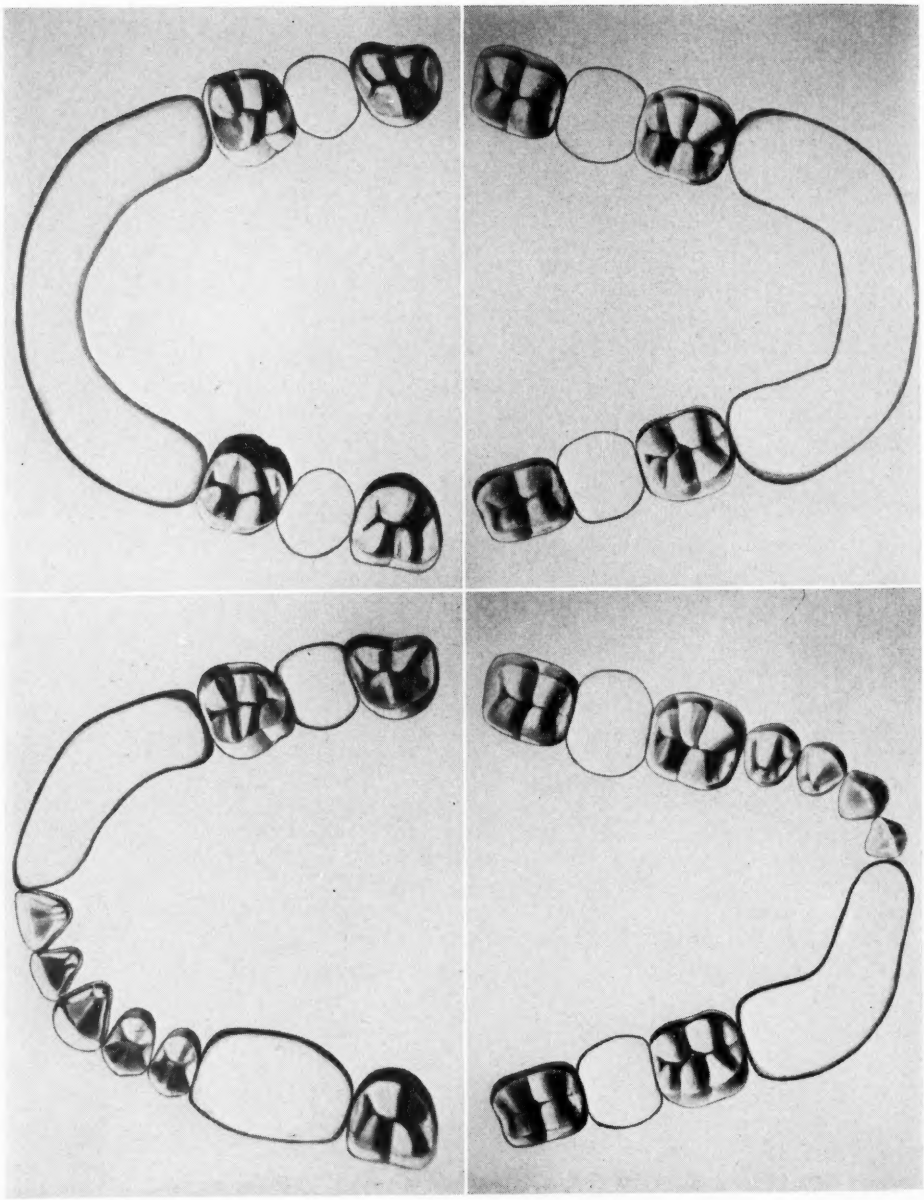
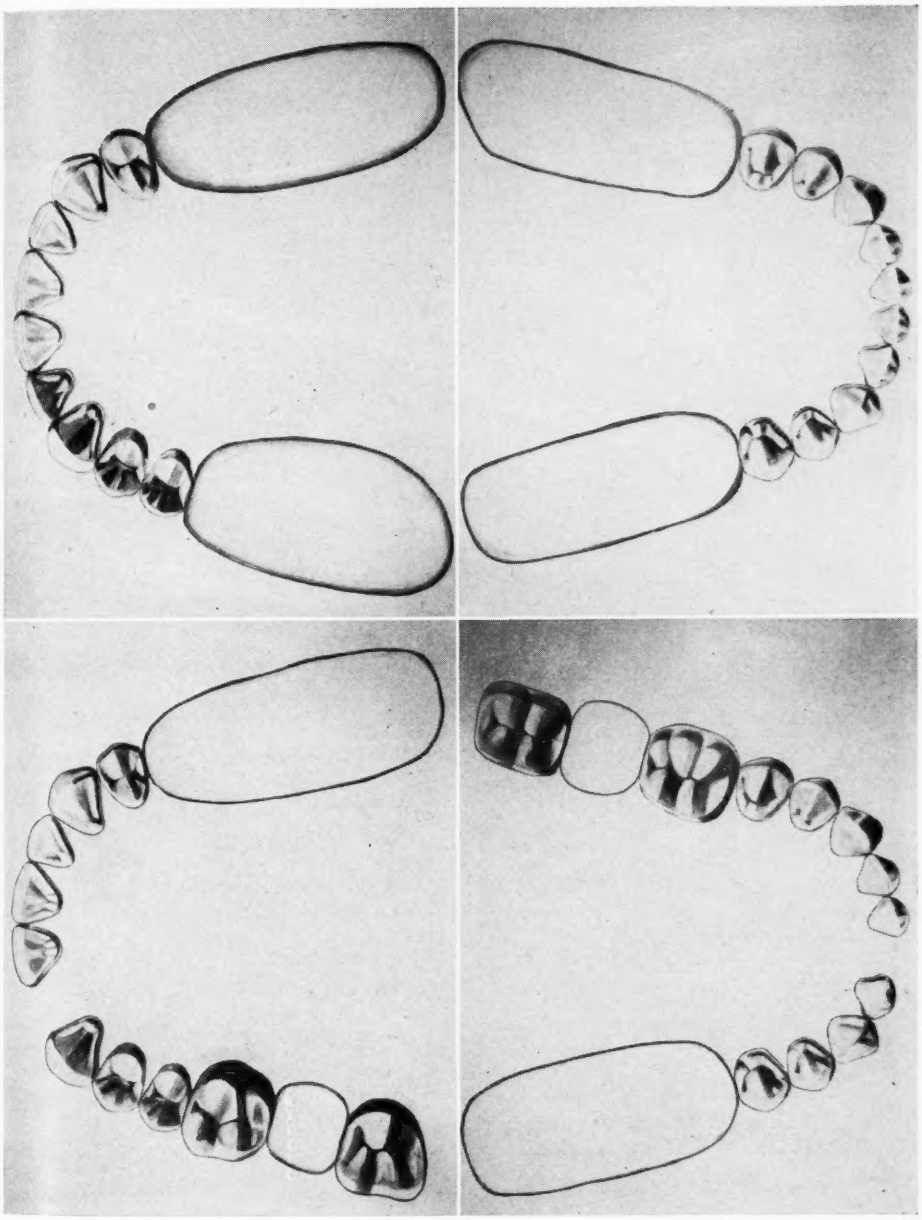


Fig. 1A.—Class I.



A. *B.*

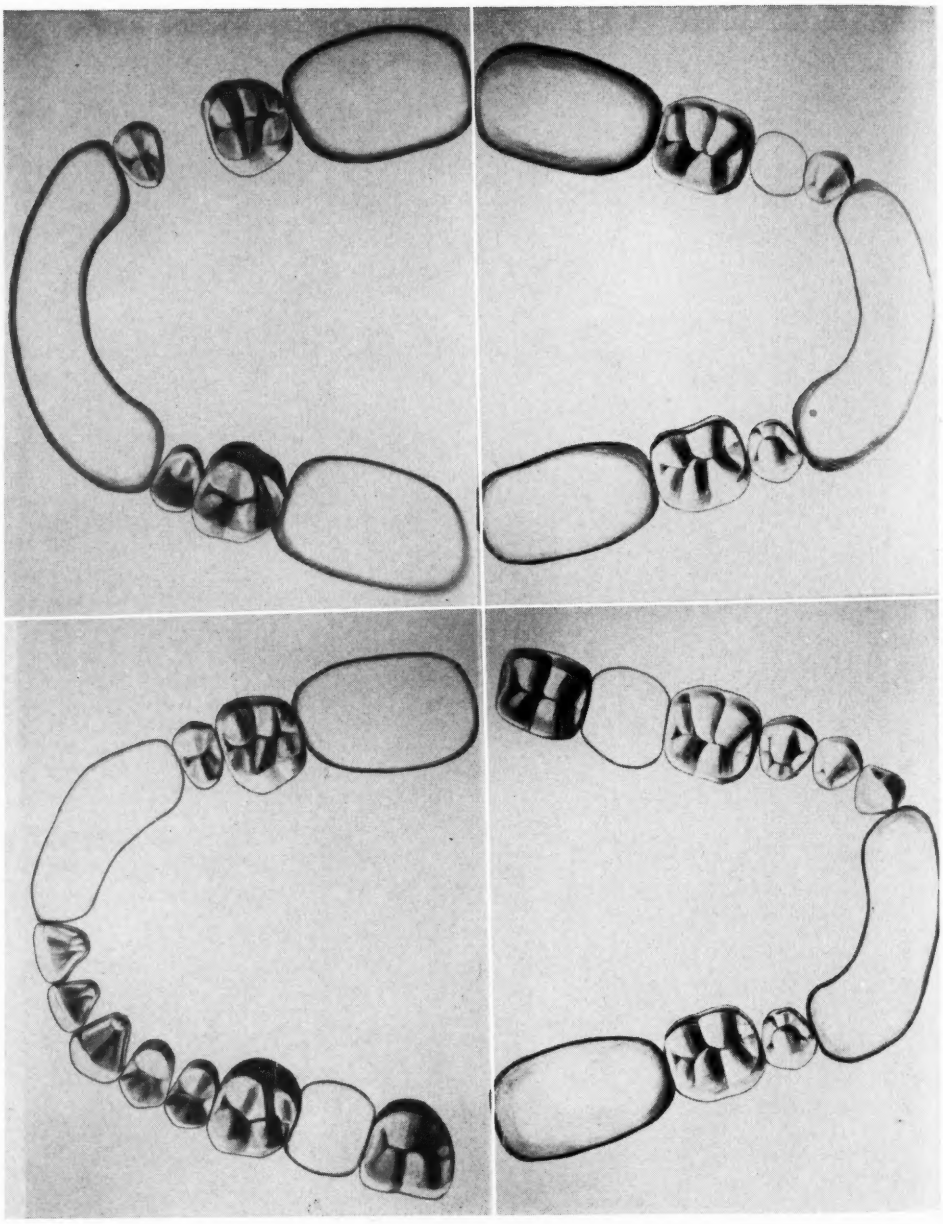
Fig. 2.—Class II. *A*, Unilateral. *B*, Bilateral.



A. *B.*

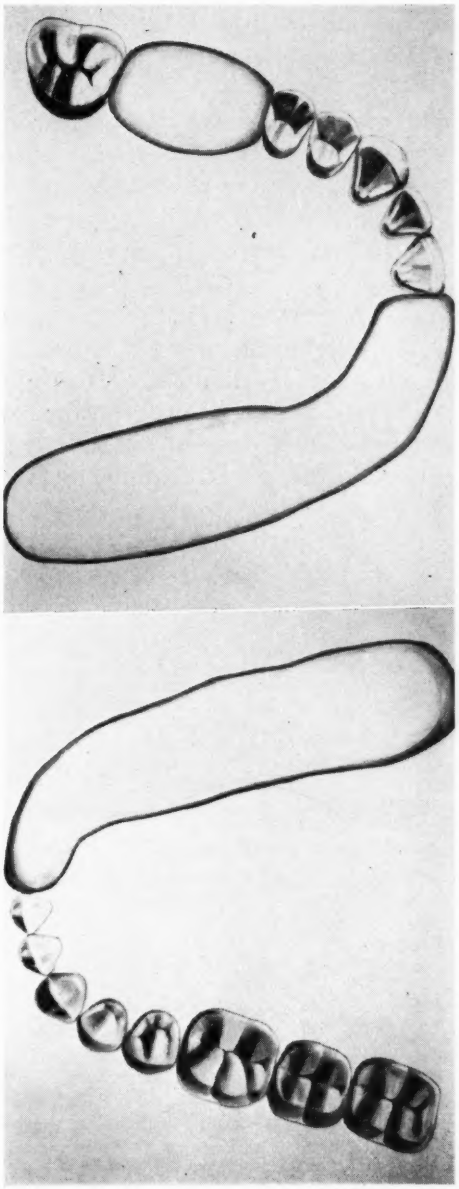
Fig. 3.—Class III. *A*, Unilateral. *B*, Bilateral.

Fig. 2.—Class II. *A*, Unilateral. *B*, Bilateral.



A. B.

Fig. 4.—Class IV. *A*, Unilateral. *B*, Bilateral.



A. *B.*

Fig. 5.—Class V. *A*, Upper unilateral. *B*, Lower bilateral.

Fig. 4.—Class IV. *A*, Unilateral. *B*, Bilateral.

CLASSIFICATION

Class I is that group of removable partial dentures (characterized by an anatomic relationship of the remaining abutment teeth) which are related both anterior and posterior to the denture base. These groups of partial dentures are found in both the maxillary and the mandibular dental arches, and they may occur unilaterally or bilaterally. This group constitutes about 14 per cent of the total classification (Fig. 1).

Class II is that group of removable partial dentures (characterized by a morphologic pattern of the remaining abutment teeth) in which all of the teeth are posterior to the denture base which functions as a partial denture unit. This group of partial dentures is found in the maxillary and mandibular dental arches and can be either unilateral or bilateral. This group constitutes approximately 8.5 per cent of the whole classification (Fig. 2).

Class III is that group of removable partial dentures (characterized by the anatomic relationship) in which all of the abutment teeth are related anterior to the denture base which functions as a partial denture base. This group is found in both the maxillary and mandibular dental arches and may occur unilaterally or bilaterally in either arch. They constitute about 72 per cent of the partial dentures (Fig. 3).

Class IV is that group of removable partial dentures (characterized by anatomic relationships) in which the denture bases are both anterior and posterior to the remaining teeth. The abutment teeth are in the center or between the functional denture bases. These groups of partial dentures are found in the maxillary and in the mandibular arches and, again, they can be either unilateral or bilateral in character. This group is approximately 3 per cent of the whole classification (Fig. 4).

Class V is that group of removable partial dentures (characterized by a specific relationship) in which all of the abutment teeth are unilateral to the denture base. This group represents about 2.5 per cent of the total classifications (Fig. 5).

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Whittier, Calif.

A FIXABLE-REMOVABLE PROSTHETIC ATTACHMENT

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A NEW FIXABLE-REMOVABLE precision attachment for use in fixed partial denture prosthodontics will be described. Its application makes possible the rigid fixation of precious metal parts of prosthetic assemblies in the mouth without soldering. It differs from the Chayes type of precision attachments, used in the construction of removable partial dentures, in that the closely fitting parts of it are mechanically fixable. Thus, restorations may be designed with its use so that parts of them may be fixed, unfixed, removed, replaced, and rigidly refixed by the dentist as desired.

The following are uses I have made of this device: (1) It was used for the rigid fixation of the precision-rest end of otherwise necessarily semifixed partial dentures when the paths of insertion of the abutment castings were impossible to parallel without endodontic treatment. (2) It was used in the rigid fixation of cross-arch lingual and palatal bar splints. By using two fixable-removable attachments, such fixed bars were later unfixable, removable (for periodic cleansing), replaceable, and refixable. (3) Rigid fixation of pontic sections was secured by the use of two fixable-removable attachments. These pontic sections, for ease of repair, could likewise be unfixed, removed, reinserted, and rigidly refixed, thus making the use of incisal porcelain replacements practicable. (4) The attachment was used in the later rigid fixation of a pontic section into a cemented restoration already present in the mouth. This was done by leaving an unused, temporarily filled (with autopolymerizing acrylic resin), female portion of the attachment in the restoration until its use as a fixed partial denture abutment was required.

MECHANICAL PRINCIPLES

The fixable-removable attachment* consists essentially of two main parts: (1) a female part (Fig. 1, *A*) which consists of a flanged open-sided tube with a closed end, and (2) a three-part male portion (Fig. 1, *B*) which consists of a flat soldering plate from which emerges a relatively narrow shank holding a larger split tube (Fig. 2, *B*), and a double-acting spread bolt and nut (Fig. 2, *A*).

Presented as a Table Clinic before the American Academy of Restorative Dentistry, Chicago, Ill., Feb. 2, 1958.

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*Acknowledgement is given for aid in the development of the fixable-removable attachment and its wrenches to the following: Dr. E. L. Whitman, Dr. F. B. Vedder, and Dr. F. A. Peyton, of the faculty of the School of Dentistry of the University of Michigan; The J. M. Ney Company of Hartford, Conn.; and The Kerr Dental Manufacturing Company of Detroit, Mich.

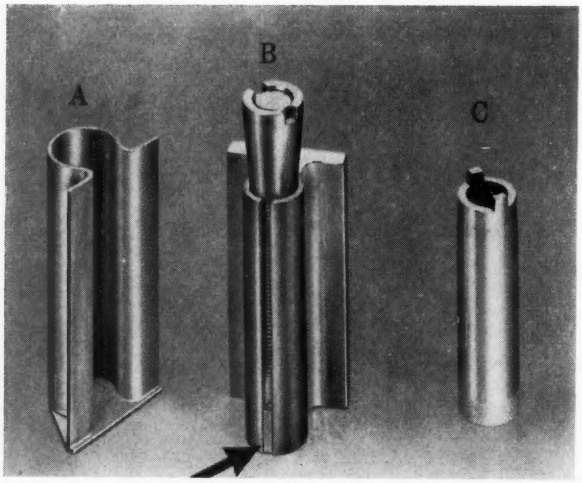

Fig. 1.—The fixable-removable attachment. *A*, The female part is a flanged open-sided tube with the cervical end closed. *B*, The assembled, three-part male portion as it is supplied. The upright portion is a one-piece, flat soldering plate from which emerges a narrow shank holding a larger split tube. The bottom of this split tube has an inside taper or flare of 5 per cent and contains a double-acting spread bolt and nut. The arrow indicates the Scullin key. *C*, The adjusting wrench.

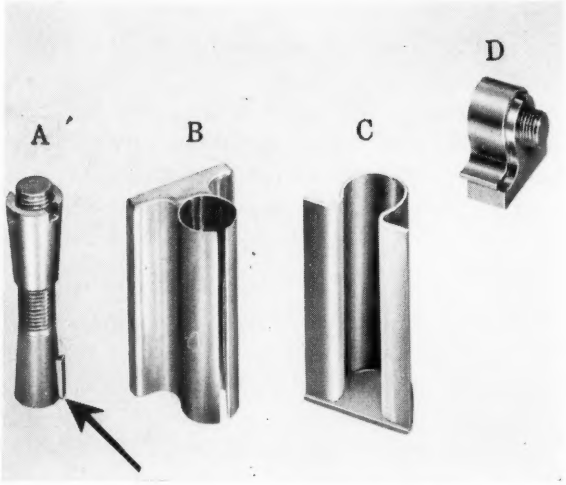

Fig. 2.—The fixable-removable attachment is disassembled after having been readied for use in a prosthesis. *A*, the double-acting spread bolt and nut. The arrow indicates the Scullin key on the bolt head. The bolt head and nut are both milled to an outside taper of 5 per cent and are mate-threaded to 132 threads per inch. *B*, The shortened male split tube. The top (occlusal) orifice (when fabricated into a prosthesis) has been given a 5 per cent inside flare or taper. *C*, The shortened female open-sided tube is shortened after it is supported in its abutment casting. *D*, The portion of the stock attachment which is unused in this application.

The male portion of the attachment fits accurately into the female part of the attachment (Fig. 3) and locks in it mechanically (Fig. 4). The split tube portion of the male part is counter-sunk originally and has an inside taper of 5 per cent in its bottom (cervical end) (Fig. 2, *B*). The 5 per cent outside tapered spread bolt (Fig. 2, *A*) fits into this flared bottom (cervical) end of the split tube (Fig. 1, *B*). A Scullin key is located (Fig. 2, *A*, arrow) on the flared portion of the spread bolt head. When this Scullin key rides in the split slot of the split tube (Fig. 1, *B*, arrow), it prevents the bolt from turning within the split tube. The female part of the attachment is best "cast in" the abutment restoration which is to contain it, but, with extreme care and skill, it can be soldered in the restoration. Viewed from the top (occlusal), the male part fits into a "dovetail" or "doll's-head" shape in the female portion of the attachment.

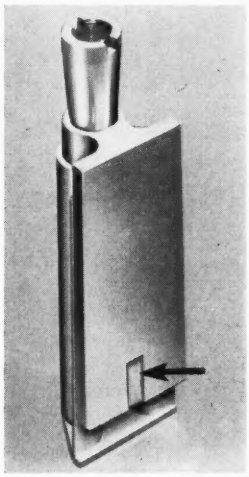

Fig. 3.

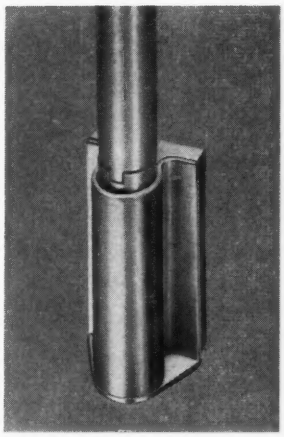

Fig. 4.

Fig. 3.—The assembled stock attachment as viewed from the soldering plate side. The male portion is just short of being completely seated. The arrow indicates the notch marking the bottom (cervical) end of the attachment.

Fig. 4.—The completely assembled attachment. The wrench is used to either fix or unfix the attachment. The wrench is used only after the female open-sided tube is contained in the abutment casting and the male split tube is attached to the prosthesis and its occlusal orifice has been flared.

Once the attachment is fabricated in a restoration, the greatest possible length of the female part, as limited by the preparation and occlusion, is rigidly supported in a casting. Then a similar length of the male portion of the attachment (minus the spread bolt and nut) is located inside the female part and adjusted to the occlusion. The top (occlusal) orifice of the seated split tube of the male portion is given an inside taper or flare of 5 per cent (Fig. 2, *B*). This provides an inside flare of 5 per cent on both the bottom (cervical) and top (occlusal) ends of the split tube part of the male portion of the attachment.

Then the double-acting spread bolt and nut are inserted inside the split tube. The tapered bolt head is in the bottom (cervical) end with the Scullin key in the split slot, and the tapered nut is on the top (occlusal) end.

The parts of the prosthesis are assembled and tension is applied to the threads of the spread nut and spread bolt with one of the wrenches (Figs. 4, 5, and 6). This causes two things to happen: (1) the spread nut descends, and (2) the spread bolt rises inside the double tapered, split tube. This forcible double action opens the split tube and jams it against the inner walls of the female portion of the attachment thus fixing the restoration.

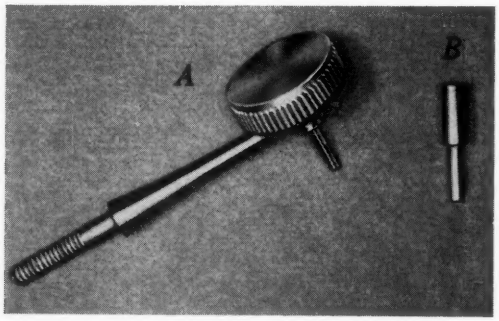

Fig. 5.—The adjusting wrenches. *A*, The oral wrench which turns in a small bearing. The wrench attaches to a cone socket handle. *B*, The finger wrench for use on the attachment when it is not in the mouth.

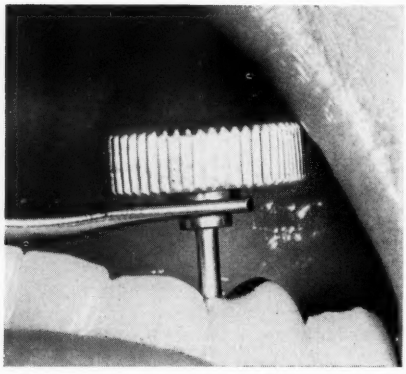

Fig. 6.—The oral wrench is applied to fix or unfix the attachment in the mouth.

To remove the prosthesis and separate the parts of the attachment, the tension on the threads of the spread bolt and nut is loosened with one of the wrenches. This action releases the frictional retention of the inner (male) split tube against the inner walls of the supported outer (female) open-sided tube. When the frictional tension is released, the parts of the attachment can be separated. It is not necessary to remove the nut from the bolt. The release of the tension on the threads, so that the nut and bolt are loose in the split tube, is all that is required.

To refix the attachment and the prosthesis, the tension is reapplied to the threads of the nut and bolt. This restores the frictional retention of the split tube

against the inner walls of the supported female part of the attachment and fixes the attachment rigidly in position.

The countersunk area in the cemented restoration that holds the spread nut is exposed to oral fluids and the forces of occlusion unless it is filled. If removal of the attachment *is not* contemplated after it is fixed in position, the space over the nut is filled with autopolymerizing acrylic resin. The end of the bolt itself can serve as an occlusal contacting surface. If periodic removal of the attachment *is* contemplated, the most cervical portion of the countersunk area (including the nut slots for engagement with the wrenches) is filled with gutta-percha or temporary stopping. The occlusal portion (above this temporary stopping) is covered with autopolymerizing acrylic resin. A heated burnisher can be applied to this plug to permit the removal of the resin and the temporary stopping and thus allow access to the slots in the nut. Then the tension on the split tube can be released and the appliance removed.

POSITIONING THE ATTACHMENT IN THE ABUTMENT

Soldering the female portion of the attachment into an abutment casting requires exacting technical execution more difficult than that required for other precision attachments. The attachment must be positioned precisely, and solder feeding must be complete. These procedures may produce distortions and disastrous hidden voids if they are not done properly. The female part of the attachment may be positioned in the wax pattern for the abutment casting, and the gold is cast to it. This procedure is preferred because it is simple, more positive, and the union between the cast gold and the female part of the attachment is adequate. The use of reducing type inlay investments is unnecessary.

An accurate master cast that contains the properly related dies of the prepared abutment teeth is mounted on an articulator in the correct relation with the cast of the opposing teeth. The wax patterns for the abutment castings are carved to the desired contour and occlusion.

A space is carved out of the wax abutment pattern for the placement of the female part of the attachment. A paralleling mandrel is used to orient the attachment. Care is taken in this placement to use the maximum intracoronal length of the attachment. Also, the proper position of the soldering plate (of the male portion) to the proposed prosthesis must be considered and determined at this time.

A paralleling mandrel can be made by carefully dressing down a straight handpiece, No. 557 cross-cut fissure burr in a lathe burr chuck. The diameter of the burr is reduced until it can be inserted easily into the top (occlusal) orifice of the split-tube male portion from which the nut and bolt have been removed (Fig. 7). The fit of the mandrel into the split tube should not be too snug nor should the insertion of the burr open or deform the split tube in any manner.

With the split-tube male portion properly placed on the mandrel, the female portion of the attachment is slipped on it (Fig. 7). The mandrels with the attachments in position on each one can be aligned with a surveyor or by eye.

The loaded mandrels serve as aligning tools, and the attachment(s) is placed in the recess in the wax pattern for the abutment casting. Wax is flowed around

the outer (female) open-sided tube, and the wax pattern is reshaped to the optimum contour (Fig. 8). Some excess metal of the female open-sided tube will protrude from the occlusal surface of the wax pattern at this time, and it is allowed to remain.

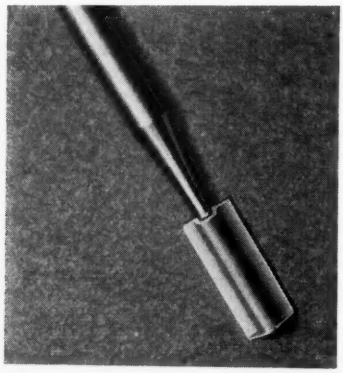

Fig. 7.—The paralleling mandrel is in the top (occlusal) orifice of the male split tube within the female open-sided tube. The nut and bolt have been removed to permit alignment of the attachment.

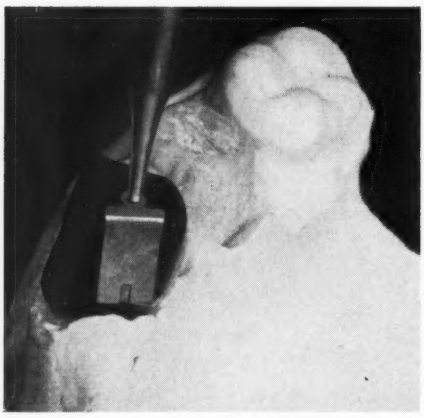

Fig. 8.

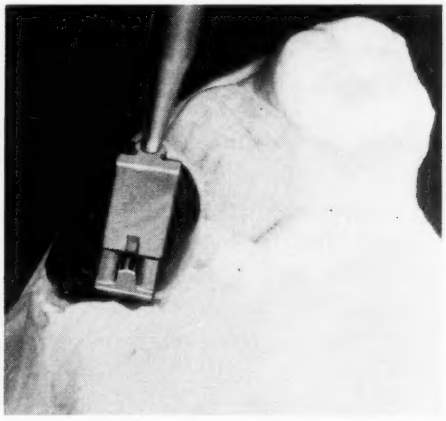

Fig. 9.

Fig. 8.—The attachment is aligned and waxed into the abutment pattern which is to hold the female open-sided tube part.

Fig. 9.—The paralleling mandrel holding the male split tube part is being withdrawn from the female open-sided tube. The female part of the attachment has been sealed in the finished abutment pattern.

The mandrel and the male split tube are now carefully drawn out of the female open-sided tube (Fig. 9), leaving the properly aligned female part of the attachment in the wax pattern (Fig. 10).

The abutment pattern is sprued (Fig. 11) and cast. After cleaning and wire brushing, the casting is placed on the master cast. The excess metal of the female open-sided tube that protrudes from the occlusal surface of the casting is carefully ground to occlusion, and the casting is polished.

The male split tube is inserted in the now supported female open-sided tube and related to the pontic or bar with sticky wax and/or plaster. The excess occlusal length of the male split tube is *not* removed until later. Antiflux is placed on the male split tube where solder is not desired, and it is joined with solder to the related bar or pontic.

The soldered prosthesis is cleaned and assembled on the master cast. The male split tube part of the attachment (minus the nut and bolt) is seated in the female part of the attachment in the abutment casting. The excess length of the occlusal portion of the male split tube is carefully reduced by grinding it to fit the opposing occlusion. The assembly is adjusted, removed from the cast, polished, and assembled again on the cast. Then the occlusal orifice of the seated male split tube is flared by using the points of Cleve-Dent No. 243 and No. 244 sugar-loaf shape plug finishing burrs. Thus, the occlusal orifice of the male split tube is carefully counter-

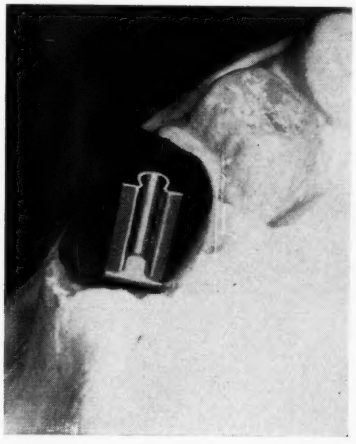

Fig. 10.

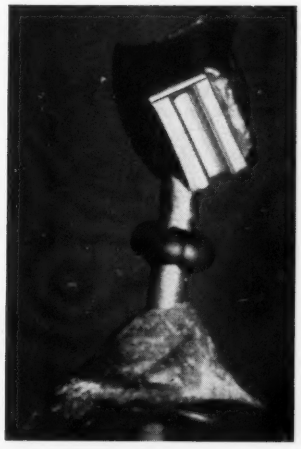

Fig. 11.

Fig. 10.—The properly aligned female part of the fixable-removable attachment is contained in the wax pattern for the abutment casting.

Fig. 11.—The abutment crown pattern containing the female part on the sprue is ready for investing.

sunk on a 5 per cent taper or flare (Fig. 12). The procedure is cautiously continued until the loose tapered nut can be inserted, point down, into the countersunk assembly so it is just short of the opposing occlusion (Fig. 13).

The entire assembly is removed from the master cast and disassembled. Under slight magnification, the tapered bolt is inserted into the male split tube from the bottom or cervical end. Care is taken to see that the Scullin key is in the split slot of the split tube when this is done.

The tapered nut is threaded on the bolt and tightened slightly with the fingers and the finger wrench. Then the excess bolt length is removed with a cutting plier (Fig. 14). *This bolt end must never be cut off unless the nut is in place and can be backed off to rethread the deformed bolt end.*

The restoration is carried to the mouth, adjusted as required, refinished, and the abutment castings are cemented in the teeth. The oral wrench is used to fix

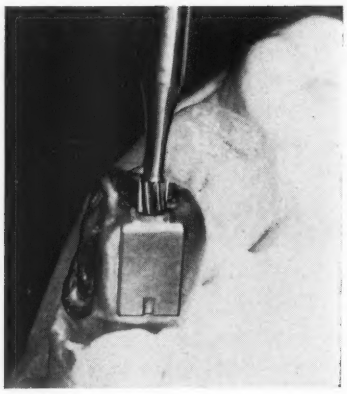

Fig. 12.

Fig. 13.

Fig. 12.—The abutment crown casting has been adjusted to the occlusion. The male split tube portion is in place and is given an inside 5 per cent taper or flare by means of plug finishing burrs. The male part of the attachment has been soldered to the prosthesis (not shown) at this time in an actual fabrication.

Fig. 13.—The tapered spread nut is loose and just short of occlusion in the countersunk orifice of the seated male split tube.

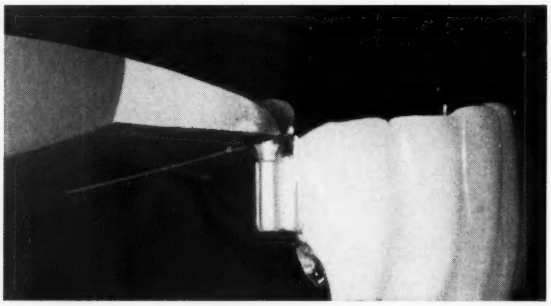

Fig. 14.—The excess length of the bolt is removed with a side cutting plier. Note: the nut must be on the bolt when the bolt is cut.

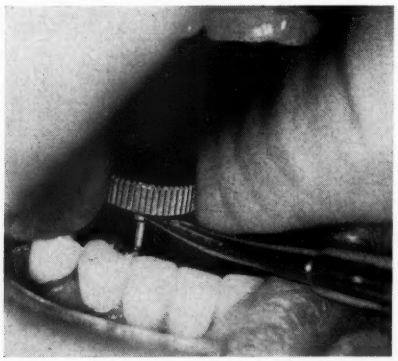

Fig. 15.—The tension on the threads of the double-acting spread bolt and nut is adjusted with the oral wrench in the mouth to either fix or unfix the attachment.

the attachments firmly in position (Fig. 15). Then a film of temporary stopping is placed over the nut. This is covered with enough autopolymerizing acrylic resin to fill the opening in the attachment level with the occlusal surface of the abutment casting. This plug can be removed if it is necessary to remove the restoration.

SUMMARY

A fixable-removable attachment for fixed partial dentures has been described. The device makes possible the construction of rigid fixation between abutments with extremely divergent paths of insertion, without resorting to endodontic treatment. The attachment can be used also for retaining pontic sections which can be removed by the dentist as required, and for rigidly attaching lingual and palatal bar splints, these likewise being removable and refixable.

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FIXED PARTIAL DENTURES

FACTORS OF DENTAL OCCLUSION PERTINENT TO THE RESTORATIVE AND PROSTHETIC PROBLEM

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A MAJOR OBJECTIVE OF ALL restorative dental service is the preservation of the dentulous and the edentulous oral structures. A fixed partial denture must rely upon the selected abutment teeth for support, and a removable prosthesis relies upon the abutment teeth and upon the edentulous areas as well. The resulting increased demand upon these tissues must be offset by an accurate relationship of the denture bases and connectors to the residual ridges and to the teeth selected for abutments. This is an exacting technical requirement.

To insure all objectives, questionable teeth which are considered clinically expendable should be removed.[1] Periodontal tissues must be returned to health, and all cariously involved teeth must be repaired. Finally, the relationship of the natural and artificial teeth must be oriented properly and stabilized in function.

This relationship requires that the reciprocal positions of the teeth in both arches, the periodontium, the temporomandibular joints, and the maxillomandibular position remain as stable as possible. A stable occlusion of the teeth requires a simultaneous bilateral reciprocal contact of all *posterior* teeth at the final closure of the jaws, regardless of whether or not the anterior teeth contact. Restoratively, a stable occlusion of the teeth necessitates that proximal contacts of the teeth in each dental arch be properly supported; occluding contact surfaces be arranged so forces applied at the final closure are distributed along the long axes of the teeth; forces transmitted from a fixed or removable partial denture to abutment teeth do not exert undue torque; and forces applied to the artificial teeth on a removable partial denture base are properly directed to the underlying bone of the residual ridge with the periodontium, muscles, ligaments, and joints in functional balance. Such an occlusion of the teeth should function and maintain the correct relationship, barring accident or disease. Wear of the parts can be controlled by periodic supervision. When required, either selective grinding, replacement of parts, or total reconstruction can be undertaken without incurring additional tooth loss (Figs. 1 and 2).

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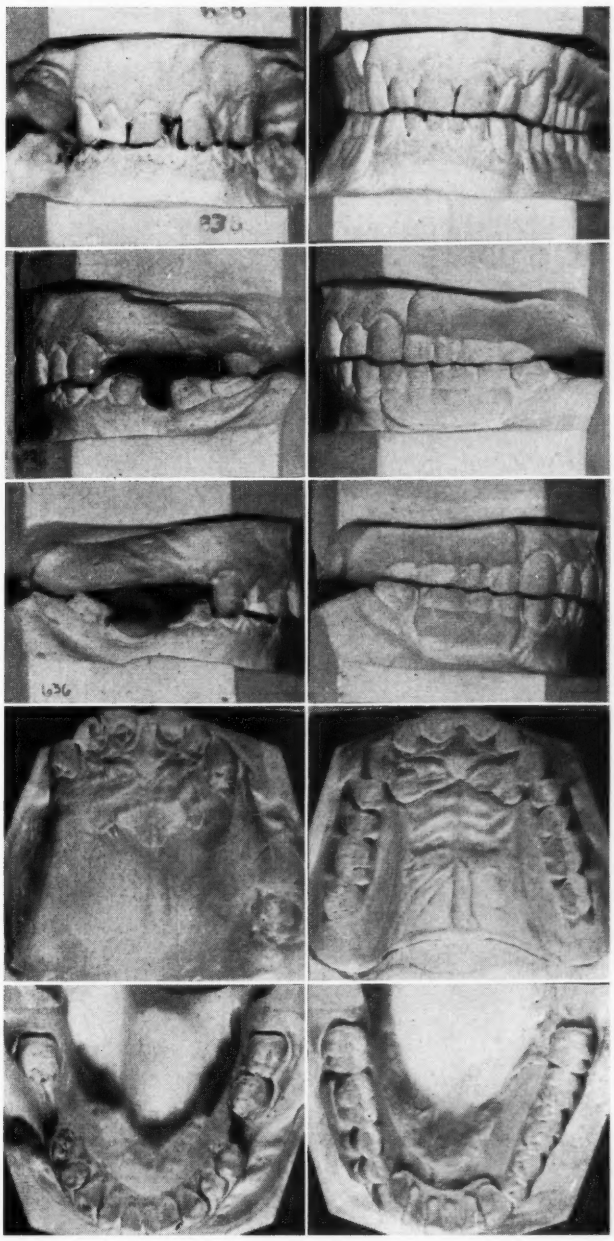

Fig. 1.—This periodontal and prosthetic problem was treated twice in 28 years. Note the extreme overlap and pathologic wear of the anterior teeth. Also note the diastema of the maxillary incisors and the treatment by permissible mesiodistal distortion of the crowns to roots. All posterior teeth are supplied by removable precision attachment partial dentures. The original treatment was accomplished in 1929, and the restorations were *remade* in 1942, and are presently in place. *Left,* The pretreatment casts. *Right,* The posttreatment casts. Note the improved anterior vertical overlap obtained by the increase of the vertical dimension, narrowing of the arch form, and modification of the occlusal anatomy of the teeth.

Three major considerations are involved in planning the occlusion of the teeth for restorative dentistry. These are: (1) factors that affect the periodontium, (2) factors that affect the residual ridges, and (3) factors that affect the maxillomandibular position.

FACTORS THAT INFLUENCE THE PERIODONTIUM

Insertion of a dental prosthesis introduces a foreign body into the oral cavity. This may affect all structures of the mouth, particularly the supporting structures of the remaining teeth.

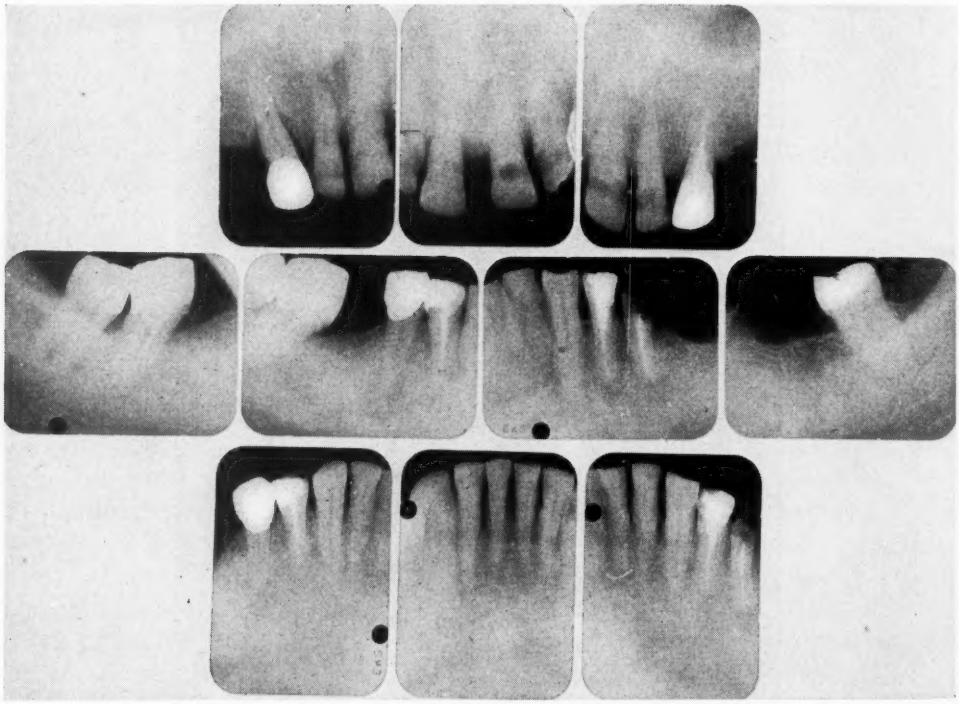

Fig. 2*A*.—Pretreatment roentgenograms of patient in Fig. 1. Note the periodontal involvement of the maxillary anterior teeth, particularly the left canine.

The periodontal membrane is continuous with the connective tissue of the gingivae, and both have a mutual blood supply. Irritation to the gingivae may result in inflammation and may have an adverse effect on other tissues of the periodontium. When a removable partial denture is required, the design of the denture base and connector must provide for proper skirting of the gingival and proximal tissues. Under all circumstances, the coronal surfaces of the abutment teeth must also be planned for function. Gingival contours and the occlusal and incisal form of all restored teeth must be shaped to shunt food and protect the marginal gingivae.

Existing malpositions of the abutment teeth or purposeful distortion of the restored crown cannot be condoned if the resulting crown-root relationship is

basically incompatible with the resistance of the periodontium. Mandibular buccal cusps, maxillary lingual cusps, and the corresponding incisal edges of incisor teeth should be formed so that applied forces will fall within the peripheral contours of the root retained in alveolar bone (Fig. 3).[2]

Proper diagnosis requires that the choice of abutment teeth be appraised on the basis of the type of root, amount and quality of supporting bone, and the health status of the periodontium. Abutment teeth must not only resist the stresses from functional forces of mastication and pernicious habits, but also must resist horizontal and vertical stresses applied to them through the partial denture.

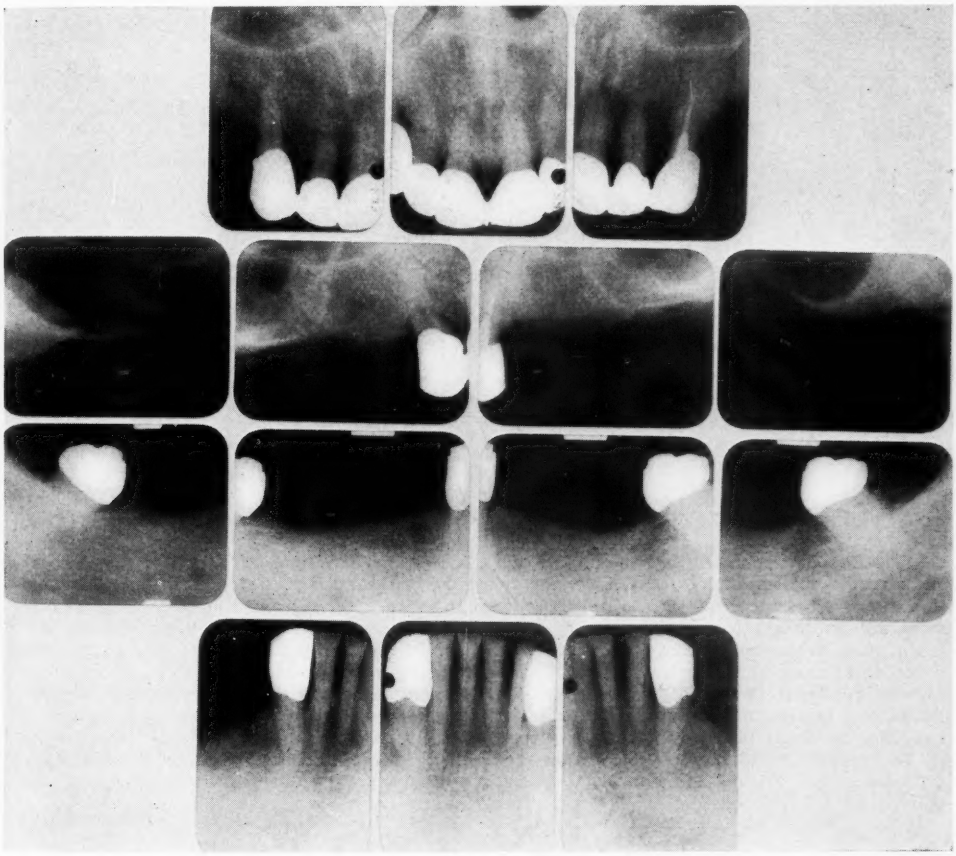

Fig. 2*B*.—Posttreatment roentgenograms of the same patient made 28 years later. Despite the reliance of the prosthesis on the anterior teeth, the functional status of these teeth has been maintained. Note the drift of the mandibular right lateral incisor because of tongue thrust.

Multiple abutments are essential to offset inadequate periodontal support, tooth mobility, or an unfavorable crown-root ratio.[1-3] However, injudicious use of splinting must be avoided: for example, when there are too few remaining teeth, or when an unfavorable periodontal prognosis or inadequate root support for individual

teeth exist. Such teeth are best removed.[1] Despite the value of fixation, optimum stability depends on the final occlusal and incisal contacts of the teeth. When teeth are restored with crowns or inlays to obtain a refined intercuspation of the teeth, but questionable abutment teeth are used, the objectives of a stable occlusion of the teeth will be defeated.

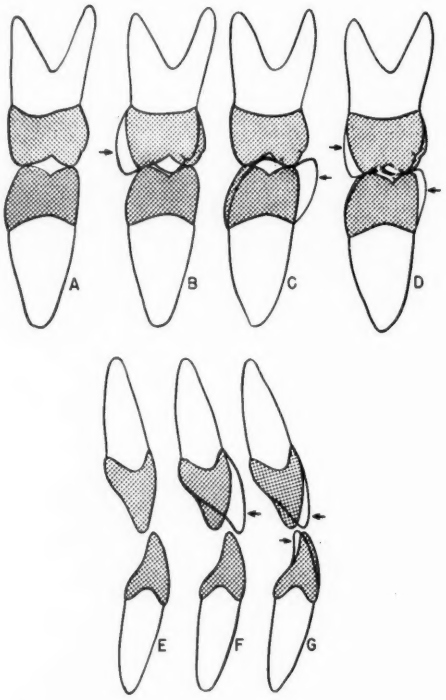

Fig. 3.—Diagrammatic representation of an incorrect tooth relationship at centric occlusion and a method of correcting it. *A*, Incorrect relationship (buccolingual view). *B* and *C*, Incorrect treatment. (The incorrect relationship is shown in cross hatching and the alterations in crown form are indicated by the arrows.) In both *B* and *C*, the alteration has been limited to one tooth. This necessitates distortion of the crown form in relation to its root. *D*, The correct treatment is indicated by the arrows. Both the maxillary and mandibular crowns are altered without distortion of the crown-root relationship. *E*, Diagrammatic representation of an incorrect relationship of the incisors at centric occlusion. *F*. An incorrect treatment attempting to remedy the condition by changing only the maxillary tooth. Distortion of the crown-root relationship results. *G*, The correct treatment. A restoration is used on both the maxillary and mandibular teeth. (Glickman, I.: Clinical Priodontology; the Periodontium in Health and Disease, ed. 2, Philadelphia, 1958, W. B. Saunders Co., Chapter 59 by the present author.)

FACTORS THAT INFLUENCE THE RESIDUAL RIDGES

When teeth are lost and not replaced, the remaining teeth may drift or extrude. Aside from the esthetic, phonetic, and functional implications of tooth loss, the original space for tooth replacements may be reduced. Teeth replaced under these conditions introduce forces that may adversely influence the function of the edentulous structures, abutment teeth, or natural opposing teeth.

Placement of teeth on a removable partial denture base requires that the opposing teeth be returned to a position compatible with the requirements for best dis-

tribution of stress between the teeth and the residual ridges. Tilted teeth receive more stress in function than those in proper axial alignment. Malaligned teeth should be moved orthodontically, either for better management of abutments, or for better relation to the residual ridges.[1] Barring this possibility, such teeth should be extracted regardless of their periodontal status. Where the malrelationships are not extreme, the teeth may be resurfaced with crowns or inlays. In some selected instances, splinting is required also as a supportive measure to offset potential traumatic resultants of force.[2,3]

Ideally, posterior teeth should be related reciprocally to each other so that the maxillary lingual cusps meet the middle of the occlusal surfaces of the mandibular teeth, and, conversely, the mandibular buccal cusps meet the middle of the occlusal surfaces of the maxillary teeth. The maxillary teeth should overlap the mandibular teeth buccally, while the mandibular teeth should overlap the maxillary teeth lingually (Fig. 4). Anteroposteriorly, terminal teeth of the maxillary arch

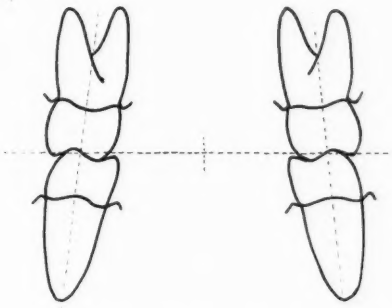

Fig. 4.—The buccolingual overlap and inclination of molar teeth.

should overlap the mandibular terminal teeth distally by approximately one-half cusp. Where this arrangement is not feasible because of drifted tooth positions, it is acceptable for mandibular terminal teeth to overlap the maxillary teeth a like amount (Fig. 5, *C*). Cusps of teeth should straddle the fossae, embrasures, grooves, or sluiceways depending on their locations in the arch. Cusps should not fit the fossae as a mortar fits a pestle but, rather, they should exhibit point-to-surface contacts with only minimum areas meeting at any functional position. Buccolingual cusp widths ideally should be narrow whether an anatomic cusp or its modification is used. A narrow intercuspal summit area is natural to normal posterior tooth morphology. The selected coronal width and height of the cusp used in the occlusorehabilitation should depend on the limitations imposed by periodontal support and resultant leverage to the roots. The same cusp form should be used consistently throughout the rehabilitated dentition. Selective narrowing of the buccolingual width of the abutments is a basic misconception in attempting load reduction. A functional occlusion of the teeth requires meticulous distribution of stress to all the roots of the teeth and correct allocation of the direction of stress from each coronal surface to each root. In this manner, load reduction can be best obtained. There is a minimal buccolingual cuspal angulation for each individual controlled by the anatomic configuration of the temporomandibular joint and the associated muscular

functions of the jaw. This minimal angulation can be determined by the use of the low-fusing metal or acrylic resin pattern technique.[4] A minimum cuspal angulation should be used where load reduction is a prescriptive requirement; otherwise, a steep cuspal incline may be used. The *mechanically* preordained steep cusp is a misconception. It is an outgrowth of mathematical formulations that are based on the function of the articulator and not necessarily on that of the mouth.

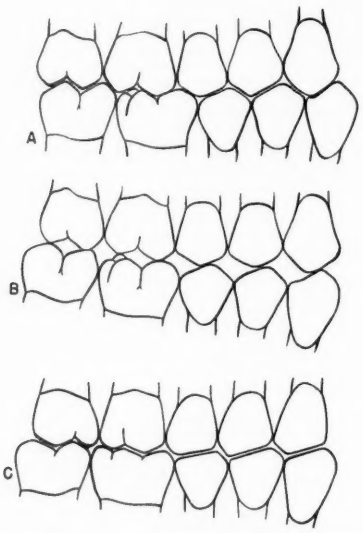

Fig. 5.—*A*, A buccal view of ideal relationships in a lateral excursion, showing intercuspation. *B*, A buccal view, showing a condition in which intercuspation is lacking in lateral excursion. *C*, The condition shown in *B* is corrected by occluso-rehabilitation. The mesial slopes of the maxillary canine and premolars and the distal slopes of the mandibular canine and premolars are modified so as to attain intercuspation. Note the changed anatomy of the maxillary molars, which includes relocating the buccal grooves and changing the size and location of the cusps. Such modifications vary with the individual needs according to the malposition of the teeth. (Glickman, I.: Clinical Periodontology; the Periodontium in Health and Disease, ed. 2, Philadelphia, 1958, W. B. Saunders Co., Chapter 59 by the present author.)

Asymmetry of the jaws and malalignment of the teeth in the arch may require a compromise of ideal objectives (Figs. 6 and 7). Rarely is it safe practice to place teeth on partial denture bases so that they are not correctly related to the residual ridges. In many instances, it is impossible to obtain a mechanically balanced occlusion of the teeth in asymmetrical jaws with malposed teeth. The distortion of tooth form to accomplish a prosthetically balanced occlusion of the teeth may not only distort the crown-to-root relationship, but it may also cause incorrect stress on the residual ridge and the abutment teeth. In these instances, a cross-bite arrangement of the teeth may be required. Indeed, there are instances in which a normal relationship on one side and a cross-bite positioning on the other side of the arch is a requirement for optimum safety. Steep cusps must not be used indiscriminately. The deep vertical overlap of the anterior teeth frequently requires the use of steep cusps on posterior teeth. They should be preferred where harmony between the function of the anterior teeth and the posterior teeth is necessary because of a deep vertical overlap. However, periodontal and crown-root leverage factors may limit

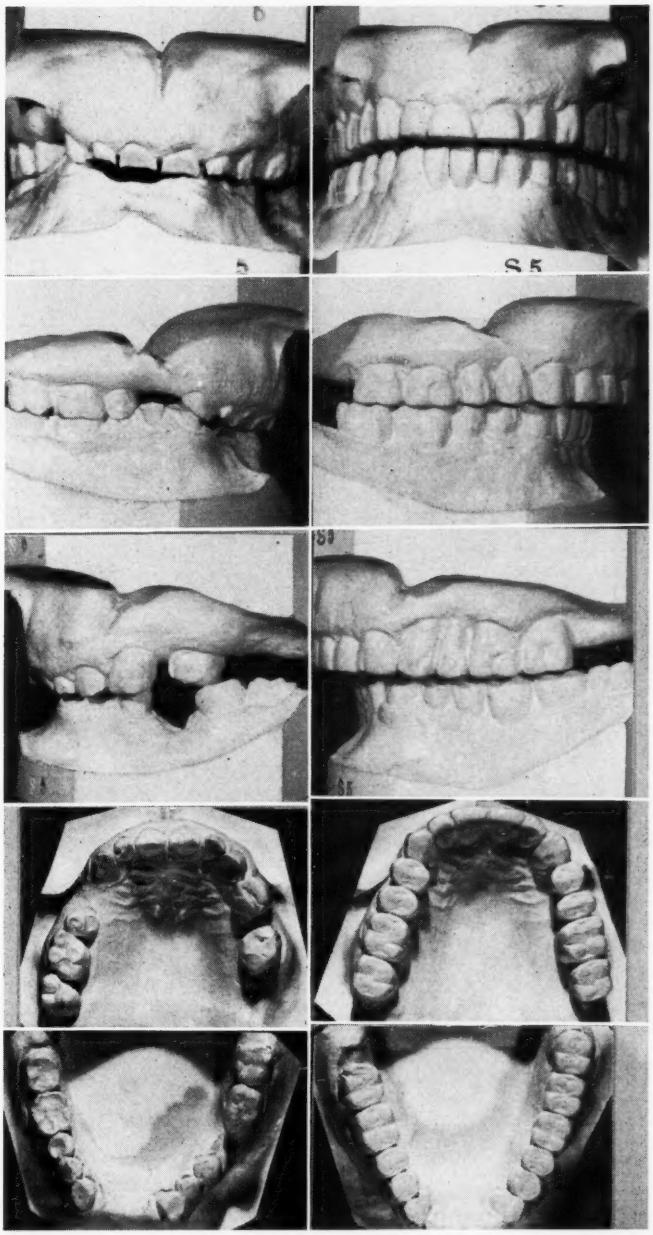

Fig. 6.—An example of a severe malocclusion where ideal objectives cannot be obtained in treatment. *Left,* Pretreatment casts. Note the advanced attritional wear, abrasion, and extreme vertical overlap of the anterior teeth. *Right,* Posttreatment casts. Note the increase of vertical dimension and the lack of contact of the anterior teeth. The buccolingual width of the occlusal surfaces has been compromised to the extreme permissible limit. Fixed splinting around the arch offsets the potentials of excessive individual tooth leverage.

the use of a normal cusp form, and sometimes arbitrary cuspal forms are required. The artificial perfection of the occluding surfaces of the teeth alone does not assure preservation of the tissues concerned.

FACTORS THAT INFLUENCE THE MAXILLOMANDIBULAR POSITION

Regardless of how perfectly the biologic and mechanical factors are applied in the arrangement of the intercuspation of the teeth, failure will result unless a relatively stable maxillomandibular jaw position is obtained.

Fig. 7*A*.—Pretreatment roentgenograms of the patient in Fig. 6. The bone height and density are excellent. Note the proximity of the pulp to the incisal edges because of advanced wear. The pulp of the maxillary right canine was exposed.

Given good inherited factors and barring accident, disease, or interference by dental therapy, centric position and the occlusion of the teeth develop ideally, and a relatively stable position occurs.[5] Normal function and proprioception develop the neuromuscular pattern and the kinematic axial centers of control. In turn, the rest position, free-way space (interocclusal distance), and vertical dimension of the

dentition become established. Maxillomandibular positions are both static and kinematic. The static position is commonly referred to as centric relation and is controlled by the cuspation. Kinematic positions are controlled by the muscles with the mandible functioning about the condyles, each of which has three axial controls: vertical, transverse, and sagittal.[6,7]

When natural teeth occlude properly through the required effective kinematic range (approximately 2 mm.), function establishes the hinge relationship of the jaws, and a natural hinge occlusion of the teeth results. Hinge occlusion of the teeth is the position of intercuspation synchronized by function to the centric position. Centric occlusion of the teeth, therefore, is the *result* of hinge occlusion and

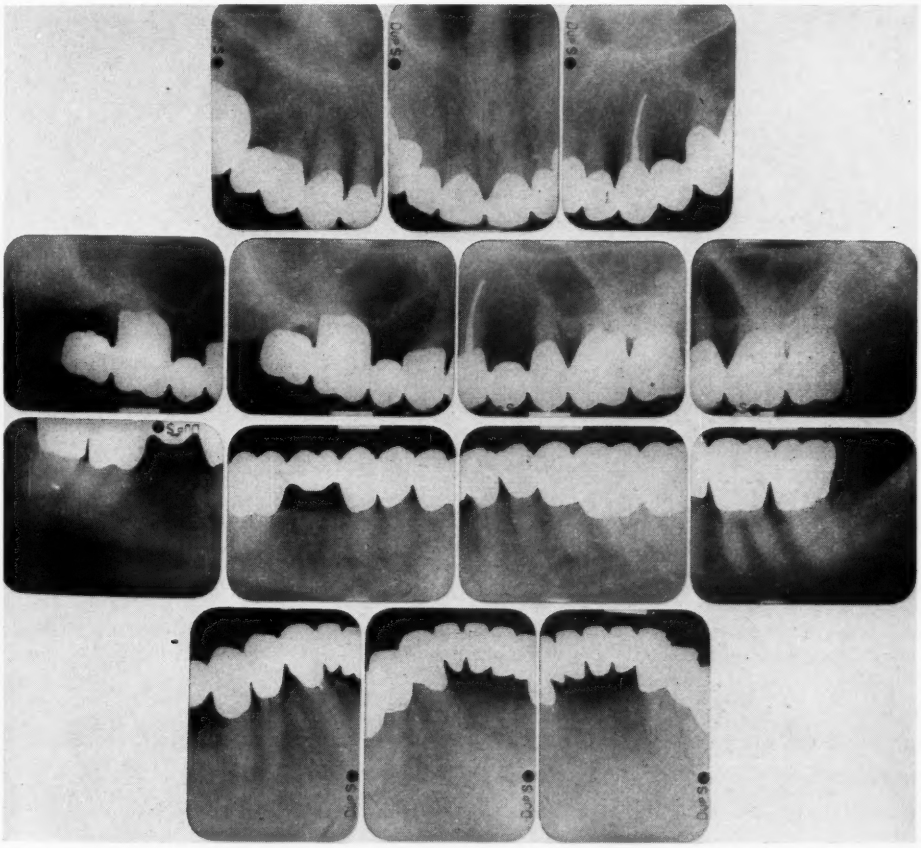

Fig. 7*B*.—Posttreatment roentgenograms made 3 years later. Note the increase of the clinical crown-root ratio within physiologic limits, the mesiodistal distortion of the crown-to-root relation, and the use of a distal extension fixed prosthesis for the maxillary left restoration.

not its origin. It is a terminal static position and cannot control jaw function.[8] In treatment, therefore, it is necessary to find or redevelop these axial controls in order to re-establish the functional occlusion of the teeth.

Malocclusion, deep vertical overlap, loose teeth, periodontal disease, loss of posterior teeth, malfitted dental restorations, pernicious habits, unilateral chewing,

or chewing on anterior teeth can alter the rest position and the location of the centric position of the jaws. The physiologic range, however, includes good as well as ideal functional patterns. That is why, in the dentulous state, the intercuspation of the teeth does not necessarily correspond with the centric position.[5,9,10] Adjustment to these developmental or physicial deficiencies leads to adaptation by every part of the stomatognathic system. This adaptive capacity is an individual entity that cannot be measured. It comes about slowly over a period of time, is not always ideal, nor is it at all times successful (Fig. 8). While all structures of the mouth

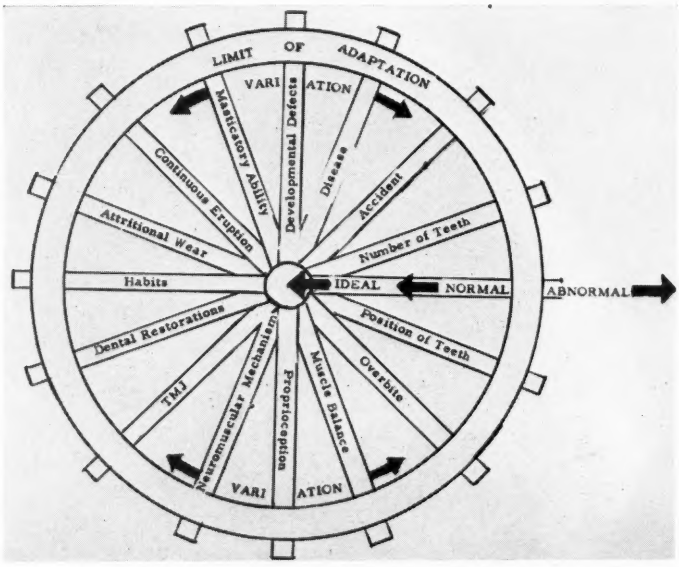

Fig. 8.—A schematic illustration of some factors that influence the maxillomandibular position. The inner circle is the ideal norm, and the arrow point is the theoretical ideal rarely seen but the optimum treatment objective. The outer circle depicts the limit of physiologic tolerance. Temporomandibular joint problems fall beyond these limits and result in a lack of adequate adaptation of the position to the various influencing factors that must be brought into physiologic balance. Asymptomatic situations are unknown borderline entities existing near the limits of adaptation.

are involved in adaptation, the adaptation of the musculature is paramount in the consideration of the maxillomandibular position. Muscles control the position of the mandible and the relation of the condyle and meniscus to the mandibular fossae. A reciprocally balanced position of all structures is important, both to centric position of the teeth[5,10] and to a hinge concept of the function of the dentition.

A dysfunctional dentition may influence masticatory ability and the chewing cycle. Disuse of the muscles affects the jaw position. Function in an eccentric or displaced maxillomandibular position results, eventually, in muscular imbalance and a change of muscle tonicity. Pernicious habits influence muscle tonicity.[11] The loss of vertical dimension changes the effective muscle length for best mechanical advantages of function. The neuromuscular mechanism, the axial centers of control, and the interocclusal distance may then become altered.[12]

Loss of the centric position can take place as an anteroposterior, vertical, or mediolateral disorientation of the condyle-fossa relationship.[13] The most commonly recognized dysfunctional pattern is vertical change. While posterior displacement is recognized frequently, the significance of mediolateral change is rarely considered. *Regardless of the direction of condylar displacement, it is important to remember that no single dimensional change occurs without possible influence on the other two components.* Clinical recognition of unbalanced musculature is difficult, but when it exists, the chance that condylar displacement has taken place cannot be disregarded. Gross condylar displacement may be evidenced by pain from muscular spasm, tenderness over the joint area, or by referred symptoms depending on the acuteness or chronicity of the situation and the predilection of the individual (Figs. 9 and 10). Crepitation or clicking of the joint structures should

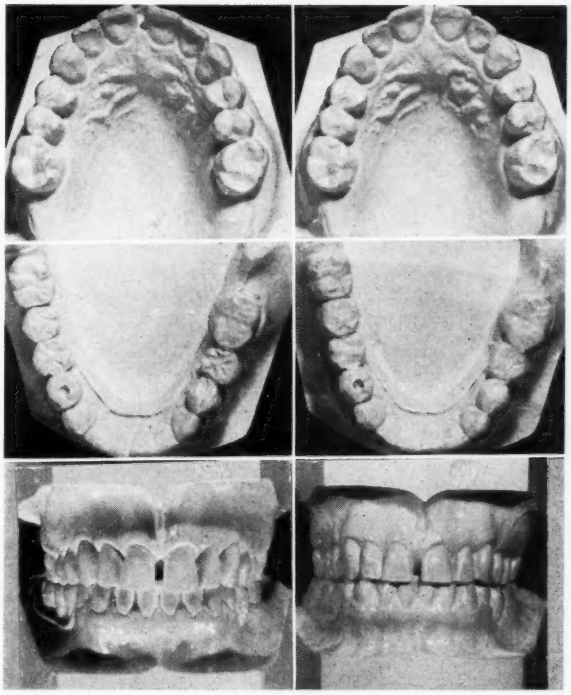

Fig. 9.—A borderline situation in which the patient was symptom free one day and in pain the next. The right condyle area was the site of pain; the patient was unable to open the mandible fully or use the teeth for mastication. The teeth on the right side of the removable partial denture were found to be in a deficient occlusal relationship. The mandible had shifted posteriorly and mediolaterally to the right. This shift probably did not come about suddenly. *Left side,* Pretreatment casts. Note the position of the midline and the extrusion of the left maxillary central and lateral incisors and the canine. There is unequal attritional wear on the lingual surfaces of these teeth as compared to the right central and lateral incisors and canine teeth. Also note the type of morsal anatomy used on the removable partial denture teeth as compared to the opposing natural teeth. This is a possible factor that led to the change of the maxillomandibular position. *Right side,* Posttreatment casts. As a temporary measure, cold-cure acrylic resin was added to the occluding surfaces of the teeth on the right side of the partial denture to increase the vertical dimension unilaterally. The extruded left central and lateral incisors and canine then came into premature contact as muscle function was re-established. These teeth were selectively ground. Note the ground unpolished surfaces and the final shift of the mandible illustrated by the midline shift to the left.

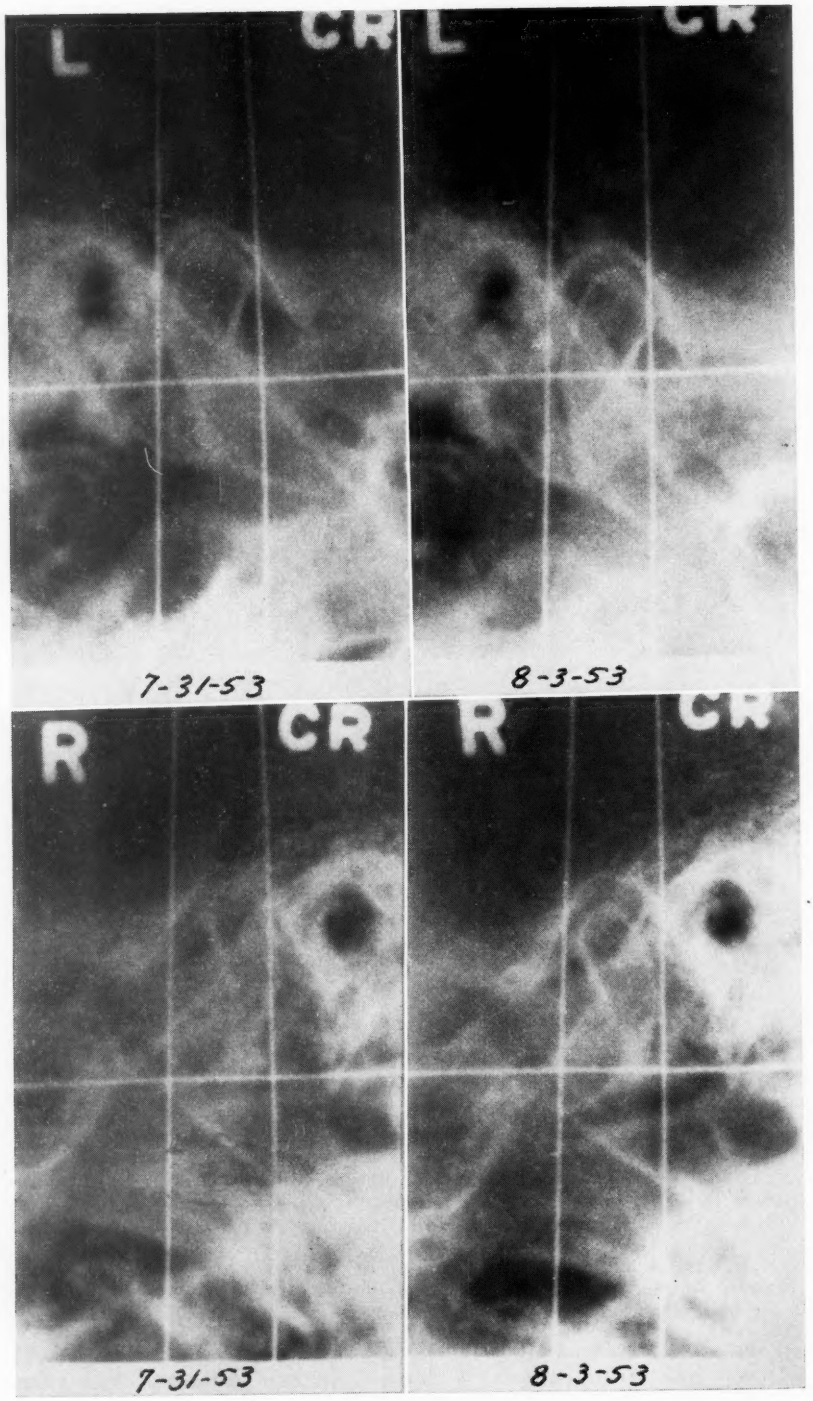

Fig. 10.—*Left,* Pretreatment temporomandibular roentgenograms of the patient in Fig. 9. *Right,* Posttreatment temporomandibular roentgenograms. Note the change in the condyle-fossae relationships. While not necessarily ideal, the change was sufficient to eliminate all symptoms.

also be considered as part of the symptomatic picture of temporomandibular joint malfunction. These are obvious clinical entities and need no diagnostic elaboration. However, *many dysfunctional dentitions do not manifest these symptoms,* yet they *may* cause disturbances to the patient once treatment by occluso-rehabilitation is undertaken. Although no history of pain exists, they should be classified as *asymptomatic joint problems* in the light of clinical reactions observed in many treated situations. Treatment of these dentitions demonstrates the same clinical problems and functional needs in the re-establishment of the maxillomandibular position.

Regardless of the concept, technique, or skills applied, management of a dysfunctional maxillomandibular position requires a redevelopment of the original centric position: one that either existed previously or would have developed naturally, barring accident or disease.[5]

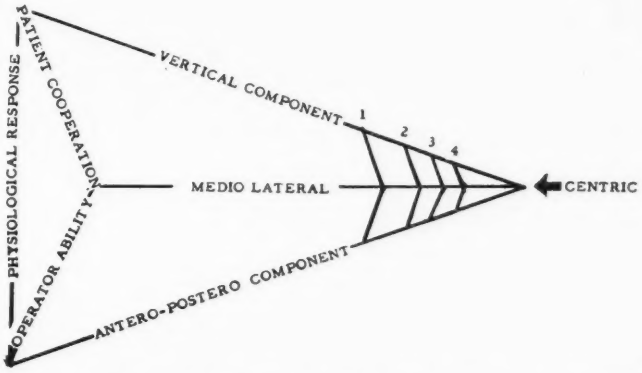

Fig. 11.—A schematic representation of the gradual reduction of the error in jaw relation recording technique. The arrow point indicates the ideal objective. Numbers *1, 2, 3,* and *4* represent an exaggerated position in which one or two components of the record are obtained. As adaptation occurs, new registrations will reduce the error. Since two condyle-fossae relationships are involved, a correct relationship of both must be eventually captured in a single record which can then be duplicated any number of times.

The usual procedure for determining the maxillomandibular position involves the use of single or multiple Gothic arch (needle-point) tracings, hinge axis determinations,[14] hinge bites (interocclusal records),[15] physiologic rest position records,[16,17] pantographic records, wax positional interocclusal records, centric relation records, chewing records, or swallowing interocclusal records.[18] Once obtained, these records are used to orient master working casts on some articulating device. Proper clinical procedure requires an estimation of the original vertical dimension of the dentition without eliminating the interocclusal distance, while at the same time maintaining a favorable maxillomandibular ridge space and crown-root ratio. When muscular spasm or muscular imbalance exists, the rest position is difficult to locate clinically. *Regardless of the method used, a primary recording by any method cannot capture the three-dimensional position of the mandible and functionally relate both condyles to their fossae.* At a changed vertical position, new demands are made upon the muscles, teeth, and joints. *Readaptation of these structures to the new demands of function takes time.* Frequently, this is a difficult and trying experience for both the patient and the dentist (Fig. 11).

Recordings of the jaw position or its movements may be registrations of a pathologic or potentially pathologic functional nature. The clinical experience of the dentist, or a patient's satisfaction with an occluso-rehabilitation are not necessarily adequate criteria for judging whether the concepts or techniques applied have been correct. Despite the various clinical successes of divergent treatment philosophies, treatment failure is not uncommon to all of these. A return to an acceptable physiologic status, rather than the capturing of the ideal situation, can be considered a clinical success. However, success cannot be ascribed to an inflexible concept or technique. Refinement of the occlusion of the teeth has not always eliminated temporomandibular joint problems. Instead, in some instances, the results of a previously workable concept applied to an asymptomatic situation have induced joint dysfunction.

TREATMENT PHILOSOPHY RATIONALE

Unless a sufficient, nearly correct vertical dimension of the dentition is incorporated as a part of the treatment plan, a return to a muscularly balanced maxillomandibular position may not occur. Bilateral increase of the vertical dimension is not always required, *and when it is required, it is not always equal on the two sides.* The anteroposterior position which is recorded is not always the same bilaterally, and it is influenced by the vertical dimension selected. With a unilaterally incorrect anteroposterior and vertical position, mediolateral displacement of the temporomandibular joint positions may occur (Fig. 12).

These facts must be borne in mind when determining and using the hinge axis, hinge interocclusal records, or a centric relation record. The forced retruded position is the position used with these methods. It is described as the most unstrained retruded position,[19] or the most distal position to which the musculature is capable of carrying the mandible.[20] Asymptomatic situations dealing with unrecognized muscular imbalance, or with conditions in which some muscle or muscles are in a hypotonic or hypertonic state, can produce an incorrect jaw position—particularly a position too far retruded if force is used. Of course, if the patient has pain on completion of the rehabilitation of the occlusion of the teeth, it becomes obvious that the result is not functional and that the treatment is wrong.

When an incorrect maxillomandibular position is recorded and the teeth are intercuspated to the most retruded position, one of two things occurs. If the musculature is "weak," the position may be accepted by the patient. Some patients, because of their temperament, will not complain, feeling that they must accept and adjust to the dental treatment. The more compulsive patients will complain, and while they may not react with pain, the dentist should evaluate critically such statements as: "My jaw feels twisted," "I feel my jaw is back too far," "I feel uncomfortable when I close my teeth," "I don't like to bite where my teeth are," "The teeth do not feel natural," "My teeth feel 'bucky'," "My teeth don't feel aligned," "My teeth feel in the way," "My teeth click when I speak," "My teeth don't meet on one side," "When I close my jaw, I feel a rock and roll." *When cuspless teeth are used, the maxillomandibular position is not locked* and these complaints are infrequent. A general complaint of not being able to masticate may be expressed, and

it may be ascribed unknowingly to the lack of cusps. However, the cause may well be an incorrect maxillomandibular position with muscular imbalance.

When the musculature is "strong," and particularly if the vertical dimension is essentially correct, reposturing of the jaw position may occur spontaneously.

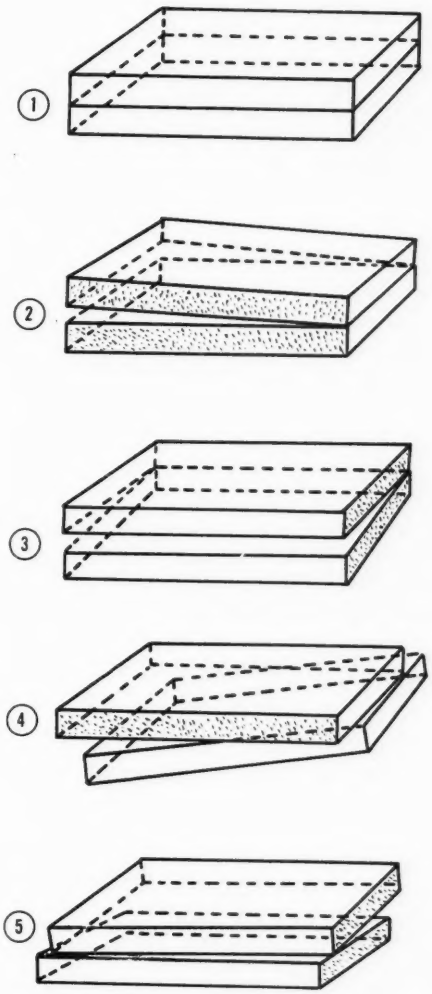

Fig. 12.—A schematic illustration of some maxillomandibular relationship discrepancies. Two slabs are used to represent the contacting surfaces of the teeth. (1) Bilateral simultaneous contact of all teeth. (2) Unilateral vertical imbalance anteroposteriorly with the mediolateral relationship being correct. (3) Bilateral vertical imbalance with a posterior prematurity. The anteroposterior and mediolateral relationships are correct. (4) Mediolateral imbalance with a vertical discrepancy on one side and an incorrect anteroposterior relationship on the opposite side. (5) Bilateral vertical imbalance with an anterior prematurity. Mediolateral as well as unilateral anteroposterior imbalance exists on one side.

Three basic changes should be recognized: anterior, mediolateral, and posterior reposturing. Typically, in an asymptomatic joint situation when anterior reposturing takes place, the posterior teeth rapidly lose their original occlusal contact so the

premolars strike prematurely. Alteration of the buccolingual overlap (an increase on one side and reduction on the other) is evidence of mediolateral change. Of course, if a removable partial denture is used, settling of the partial denture base can produce this same effect (Fig. 13). However, on a newly constructed removable partial denture with a controlled fit of the denture base to the tissue and to the abutments, this assumption cannot be made.*

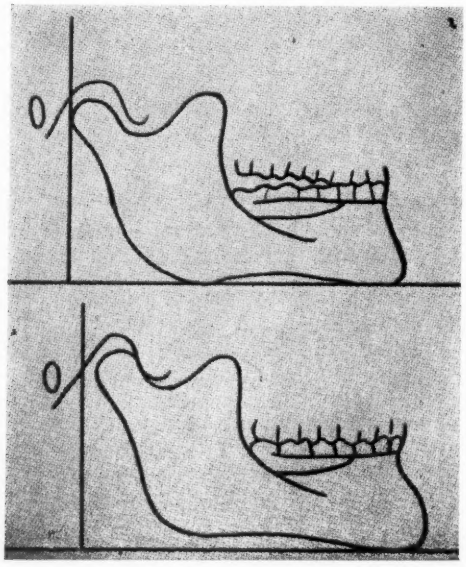

Fig. 13.—Schematic drawing to show the more intimate relationship of the condyle with the articular slope of the glenoid fossae which results from muscular pull after the loss of occlusion distally. (From Steffel, V. L.: Relining Removable Partial Dentures for Fit and Function, J. Pros. Den. 4:508, 1954.)

Clinical evidence that the maxillomandibular position has changed and that muscle function has been altered can be demonstrated in the following manner: The removable partial denture and all associated restorations are removed for 24 hours; then, upon reinsertion, a repetition of the loss of posterior occlusal contact is once more demonstrable.

Speculation as to what has happened in this situation may be rationalized on the basis that new functional demands on the muscles are occurring, stimulated by the change induced by the cuspation. An improved external pterygoid muscular function may be altering the condyle-fossa relationship, producing an anterior descent of one or both condyles. The mandibular position then becomes changed *anteriorly and mediolaterally.* This change increases the vertical distance between the jaws with a consequent separation of the posterior teeth, unilaterally or bilaterally, in unequal amounts (Fig. 14).

*The final assembly of both fixed and removable partial dentures is accomplished by the use of a relationship impression made in the mouth. The removable partial denture base is preferably a metal base (obtained by a nonpressure technique) which serves as the soft tissue abutment; the crowns or inlays serve as the hard tissue abutment.

The usual decision is to treat this situation by selectively grinding the premolar prematurities as they become apparent. If the reconstruction or prosthesis is transferred to the articulator by use of a new interocclusal registration, the limitations of this treatment will be obvious. If the selective grinding is done in the mouth, an attempt to bring the posterior teeth into contact may result in a return to the former reduced vertical dimension with all of the potentials of relapse to muscular imbalance and condylar displacement. In these instances, if cusped teeth are used, despite a demonstrable interocclusal distance, it is not infrequent that patients complain of teeth feeling high or clicking during speech. Removal of the prematurities by selective grinding does not eliminate the interferences and, strangely, it may increase the patient's complaints.

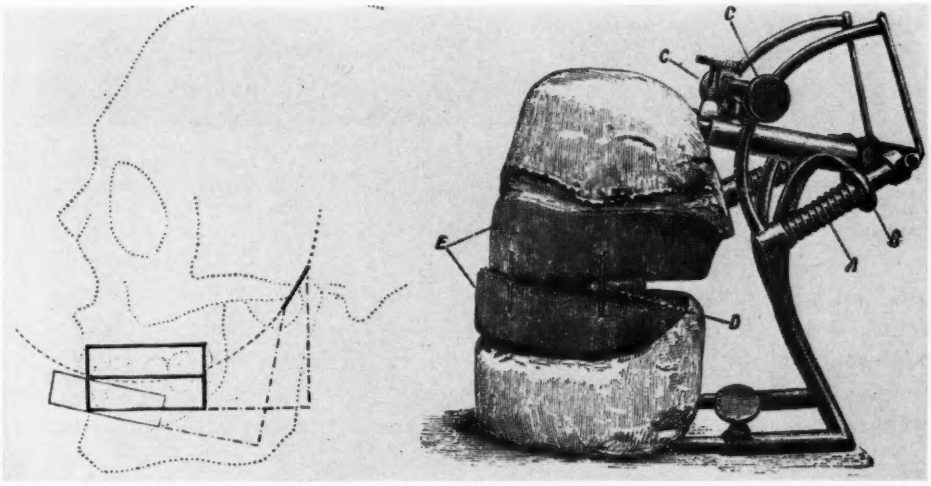

Fig. 14.—Christensen's phenomenon can be likened to the anterior spontaneous reposturing that occurs at times. Forward movement of the mandible follows the anatomic relationship of the condyle to the fossa controlled by its musculature. (From Prothero, Prosthetic Dentistry.)

At times, abutment castings are ground through until the prepared tooth surfaces are exposed. This can hardly be regarded as evidence that the originally selected vertical dimension was excessive, or that a physiologic rest position was not established originally with the required interocclusal distance.

The correct approach to treatment requires that new records be made and that the *posterior teeth be raised by rebuilding or resetting them.* In most instances, this second transfer is still insufficient to accomplish the objectives of a stable occlusion of the teeth. A repetition of the previous experience may again be encountered. Several transfers between the mouth and the articulator spaced over a period of time are necessary to establish the physiologic intervals required for re-establishment of balanced muscle function of the jaws. Each successive transfer from the mouth to the articulator may disclose a further anterior repositioning, possibly accompanied by a mediolateral change. Despite the fact that successive transfers are recorded by restrained retruded manipulation of the mandible, a more anterior

position than the previous registration may be disclosed. Barring unusual pathologic situations, a stable retruded position should be obtained eventually without the use of force.

If a removable partial denture is part of the restorative treatment, upon reinsertion of the removable partial denture the repositioned posterior teeth may be found to be in hyperocclusion (Figs. 15 and 16). Temporarily, the partial denture

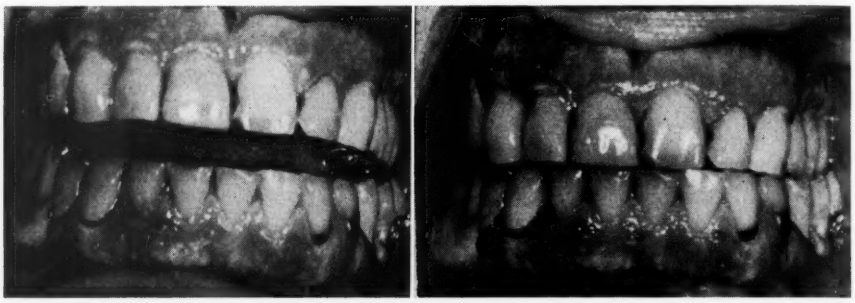

Fig. 15.—The problem of recording jaw relations. *Left,* A patient with a symptomatic joint. A most careful centric relation record may result in the maxillomandibular position showing premature molar relationships when the most distal position is used. *Right,* This relation existed five minutes later. The problem is which relationship is correct?

base may cause pressure on the supporting tissues and give rise to some tissue irritation. In view of the fact that the tissues did not react previously in this manner, the reaction is not likely to be due to border overextension. In all probability, the muscles would be reacting to the re-established vertical dimension. If the occlusion of the teeth is correct, this effect will quickly disappear. If the teeth remain in hyperocclusion, the maxillomandibular recordings should be repeated and then, dependent upon the degree of prematurity disclosed, the teeth should be selectively ground or once again repositioned.

A more frequently encountered situation is posterior reposturing of the mandible.[21] When this occurs, the posterior tooth prematurities cause pericementitis of the teeth or irritate the ridge tissues. Here the jaw is *retruding spontaneously and further efforts should be made* to use the forced retruded position. New interocclusal records are made and the casts are rearticulated. Selective grinding usually is sufficient to correct the deflective contacts of the teeth. Where concomitant mediolateral reposturing also takes place, it may be necessary to rebuild the occluding surfaces or reset the teeth. Again, if a removable partial denture is used, since the denture bases or borders originally tested were correct, adjustments of these areas are to be avoided. The soreness is caused by malocclusion of the teeth and the resultant forces acting on the removable partial denture base.

DISCUSSION AND CONCLUSIONS

The re-establishment of the maxillomandibular position is the most difficult phase of obtaining a stable occlusion of the teeth and the proper function of the jaws. Habitual jaw postures, abnormal masticatory patterns, and pernicious habits

modify the neuromuscular pattern of jaw movement and positions. Imbalance of the musculature makes it difficult to register the maxillomandibular position accurately.

Regardless of the concept or technique used, in markedly disbalanced and obviously afunctional maxillomandibular positions, the following method of treatment is suggested routinely: A muscular relaxant such as mephenesin is administered alone, or in combination with glutamic acid in the correct dosage. This premedication will tend to offset undisclosed muscular spasms and counteract muscular imbalance because of possible differences in tonicity of the various muscles. Initially,

A.

B.

C.

Fig. 16.—*A*, An asymptomatic temporomandibular problem of a patient who habitually clamps her teeth. A needed repair required the patient to be without her partial denture for 48 hours. A centric relation record was made in this position. *B*, The removable partial denture was reinserted, and this marked premature molar contact was disclosed. *C*, The occlusion of the teeth fifteen minutes later. Thirty minutes after this interval, with no treatment instituted, the relationship returned to the original status.

following this premedication, the use of the physiologic rest position, chewing records, swallowing interocclusal records, and deliberate condylar repositioning[22] may be required rather than the use of a centric relation record. The method of choice depends upon the diagnostic evaluation of the functional status of the dentition, based on clinical study of mandibular movements and roentgenographic evaluation of the joint positions both at rest and at centric position. When hinge axes are determined and used, it must be recognized that these axes may eventually change

(Figs. 9, 10, and 17).[23] In these instances, one condyle originally reacted to the causative factors of the dysfunction. Therefore, a correct bilateral hinge determination may be difficult to make at this time. The direction of restrained (not forced) hinge movement should be directed to the "nonaffected condyle" in order to determine a usable hinge in the condyle basically involved in the dysfunction. To facilitate the ultimate aim of treatment, regardless of the use of hinge axes and hinge interocclusal records, a conditioning appliance, such as an occlusal splint or preferably a bite plane, should be worn. At the minimum, a bite plane will be required overnight. However, more frequently, its use over a longer period of time is important in order to eliminate the muscle dysfunction caused by cuspal interferences which are responsible for maintaining the muscular imbalance.

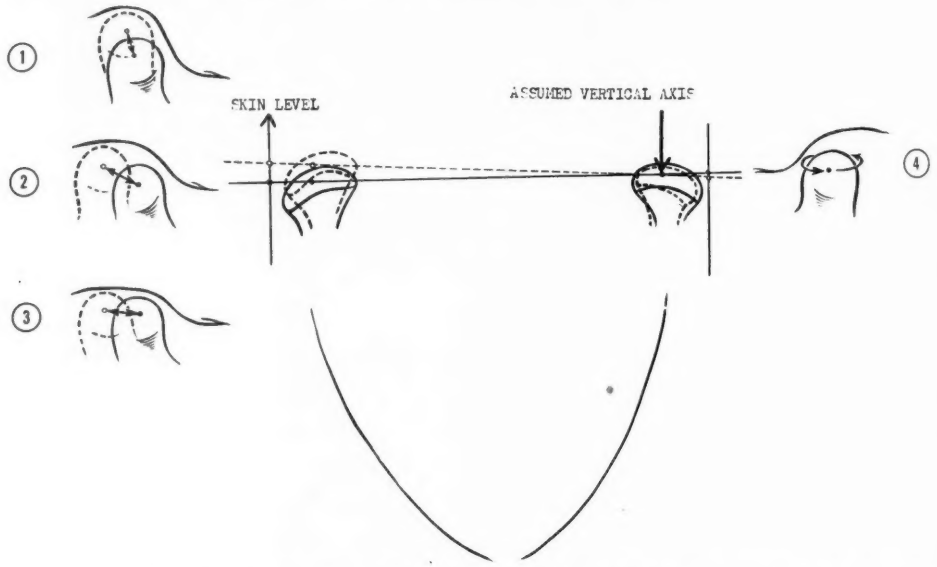

Fig. 17.—A schematic illustration of change in the hinge axis where condyle displacement exists. The dotted lines represent the original situation; the solid lines represent the post-treatment change. Note that vertical and horizontal change is influenced by the shape of the fossae (1, 2, 3) and that the movement of the opposite condyle is primarily rotational. Hinge change at the skin level on the side of rotation may be scarcely detectable clinically. (The hinge axis is represented by an intercondylar line. The question of inter- versus intracondylar axis is not portrayed since it is not germane to the problem.)

Since three dimensions are involved in the maxillomandibular relationship, any method of approach to treatment will represent the *beginning* of a series of registrations and not a final one. The initial objective should be to establish, on a temporary basis, an approximation of the final maxillomandibular position by re-stimulating muscular function.

Temporary restorations can approach, but usually fall short of fulfilling, the best requirements of fit and relationship. Therefore, proprioception and function are not fully established until the final restorations have been installed. Furthermore, it is important to remember that *periodontal fibers re-establish themselves to the demands of new function.*[24] Therefore, temporary cementation is required for variable intervals.[25]

Until evidence of equalization of forces is demonstrated by the even thinning out of wax, either by the use of chewing or excursive jaw movements, permanent cementation should be postponed. Any cementation must establish a rigid relationship of the restored coronal surfaces to the root, or the objectives of a stable occlusion of the teeth will be defeated. Cementation may introduce minute changes in the occlusion of the teeth. At times, selective grinding in the mouth is necessary since articulators cannot incorporate all of the factors related to actual mouth function.

To maintain a stable occlusion of the teeth, chewing records and lateral positional records may be required to determine the need for selective grinding in the ever-present battle between continuous tooth eruption, unequal attritional wear, differences in restorative materials used, and the uncontrolled habits of the patient.

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THE ACRYLIC RESIN TRANSFER PATTERN

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OCCLUSION RIMS ARE USED in denture prosthesis to transfer the maxillomandibular relationships to an articulator. Information such as occlusal plane location, vertical dimension, length of anterior teeth, position of the median line, lip contour, facial contour, and other pertinent data can be conveyed by these rims. The occlusion rim supplies the missing substance provided previously by the natural teeth.

When occluso-rehabilitation or partial denture reconstruction is needed, the occlusal and incisal surfaces of the teeth which maintained the existing vertical dimension of occlusion may be ground away. If the anterior teeth are present and require no reconstruction, the vertical dimension is fixed. However, the conditions which have brought about the need for reconstruction of the posterior teeth have usually produced some closure by attrition and a possible shifting of the anterior teeth. The missing tooth substance should be supplied to facilitate the establishment of an occlusion, to transfer the maxillomandibular relationship to an articulator, and to convey information to the laboratory technician.

The transfer pattern has the necessary requirements to perform all of these functions. It is particularly suitable in the determination of the maxillomandibular relationships. This is a delicate and precise procedure and requires ability and dexterity on the part of the dentist and also the cooperation of the patient. Any unaccustomed bulk in the oral cavity offers an obstacle to the patient's ability to cooperate sufficiently in order to obtain the best results. Because the transfer pattern can be formed to near normal size and shape, this deterrent factor can be minimized. When a free-end prosthesis is indicated, the bases supporting the rims, and the rims, should be trimmed to the minimum width to attain the same results.

HISTORY

Bailey[1] introduced the use of low-fusing metal as a transfer medium to seat dies, and a technique for completing a restoration on one master cast. The value of the transfer was enhanced by Cohn,* who introduced tooth form into the pattern in order to include basic factors for establishing the occlusion of the teeth. When the need for more accuracy in jaw relation records became apparent, Cohn[2] introduced the gold thimble technique in conjunction with his resin-faced cast gold

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*Cohn, L. A.: Presented before the Prosthodontia Section of the First District Dental Society of New York, 1942.

crown. The pattern in the present technique is carved carefully to substitute for missing tooth structure. Thus, the diagnosis of each problem of reconstruction is facilitated since the vertical dimension, rest position, lateral protrusive, and centric positions can be appraised properly.

The advent of cold-cure acrylic resins has made possible their use as a substitute for the low-fusing metal. The plastic is preferred over the metal for several reasons. The low-fusing metal grindings may, at times, prove toxic, and care must be taken when grinding the patterns to prevent the particles from being inhaled or swallowed. The metal patterns require some form of adhesive for retention. The acrylic resin pattern, when properly finished at the margins, requires no adhesive for retention, and its more natural color and texture helps in the alignment and contouring of the anterior teeth.

CONSTRUCTION

The acrylic resin patterns are formed on the individual dies of the prepared teeth. The die is lubricated, and a collar of Mouldine or wax is placed below the gingival margins. The die is then wrapped with a stiff paper which is held in place with a spring clip to form a tube (Fig. 1). Small amounts of polymer and monomer

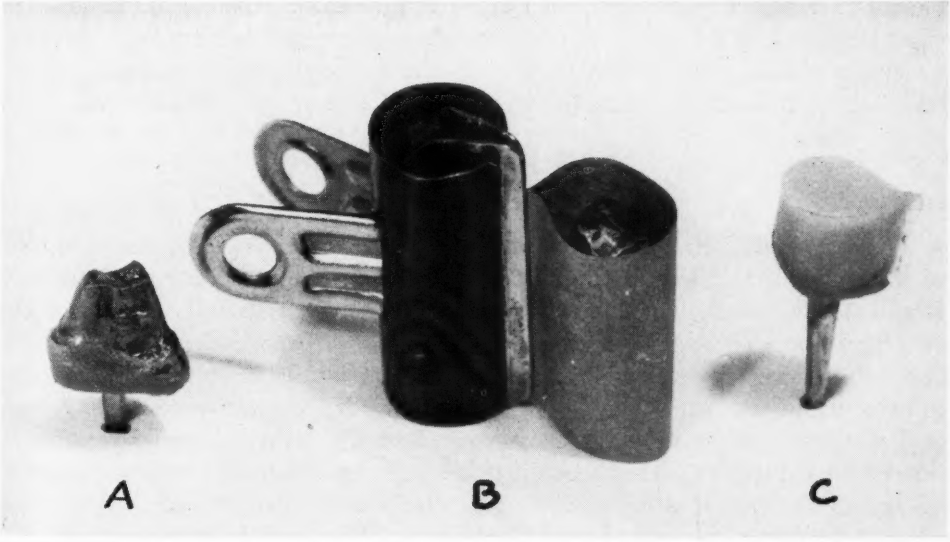

Fig. 1.—*A*, The lubricated die with a collar of Mouldine placed below the finishing line of the preparation. *B*, Stiff paper, wrapped around the die, is held in place with a paper clip. *C*, The block of acrylic resin ready for shaping.

are dropped alternately into the tube until it is filled. The resulting block of acrylic resin should extend slightly beyond the margins of the preparation and should fit them accurately. The patterns are placed on the master casts and ground to approximate tooth and dental arch form.

GRINDING THE PATTERNS

The resin patterns are placed on the teeth in the mouth in order to check the marginal fit and contact points; after which they are removed. The grinding of the patterns is done in two stages.

First Grinding Stage.—The objectives of the first grinding stage are: (1) to establish the correct vertical dimension of occlusion, (2) to provide equal distribution of occlusal thickness between the upper and lower posterior teeth, (3) to provide simultaneous, even contact on closure, and (4) to establish the proper cusp-fossa relationship.

Deflective occlusal contacts will be present continually during the grinding of the interferences of the patterns upon closure. This condition always induces external pterygoid muscle contraction which results in protrusive or rotational change in the position of the mandible. To insure simultaneous, even contact upon closure in centric relation, it is necessary that all interferences be removed in this jaw position. The best way to avoid eccentric closure is to eliminate, as much as possible, all involvement of the closing muscles of the mandible. This can be done by instructing the patient in complete relaxation of the muscles of the jaw. Tranquilizing or muscle relaxing drugs can be very helpful. The mandible can then be swung shut manually while the condyles are held back in their proper position. Too much retrusive pressure is to be avoided as this too will stimulate external pterygoid muscle activity. The more the patient can relax the closing muscles, the less is the effort necessary on the part of the dentist to keep the mandible retruded. The ideal amount of manual effort is just enough force to resist gravity. The dentist should train himself to have the ability to detect any muscular resistance to the free swing of the jaw.

PROCEDURE

The vertical dimension of occlusion is dictated by the physiologic rest position of the mandible.[3] When the muscles supporting the mandible are at physiologic rest, or tonus, and the mandible is held in this position, a space is maintained between the upper and the lower teeth. This space, called the free-way space (interocclusal distance), is fairly constant and is necessary to maintain muscle tonus and to prevent fatigue.

Many serious consequences may result from the failure to provide sufficient interocclusal distance or clearance. If it is eliminated, the oral musculature makes every effort to restore it at the expense of the periodontium, the occlusal surfaces of the teeth, or the temporomandibular joints. The presence of the interocclusal clearance permits the speech sounds to be made without tooth contact.

The sounds which bring the teeth together in their closest proximation without contact are the sibilants *(s, sh, ch, zh,* and *j)*. Thus, it is possible to test for the interocclusal distance. Although the interocclusal distance varies as a rule from 2 to 4 mm.,[4] it is sufficient for practical purposes to make sure that the teeth are free of contact when the sibilants are enunciated. The patient is able to detect any tooth contact while making the sibilant sounds. The opening that results will be the maximum permissible interocclusal distance, and the laboratory technician will

know that the vertical dimension of occlusion cannot be reduced beyond this point. This test, of course, is made only after the transfer patterns have been reduced to their proper height.

However, another test may be used to approximate the interocclusal distance at the outset and to act as a guide in the reduction of the transfer patterns. When the patient is sitting erect and a humming sound is made, the teeth are separated usually by the approximate amount of the correct interocclusal distance. The space can be observed if the lips are parted by the dentist while the patient continues to make the humming sound.

Fig. 2.

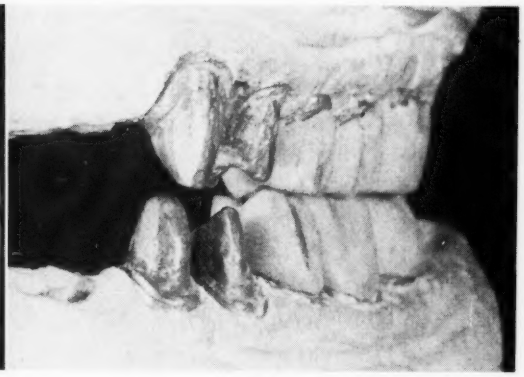

Fig. 3.

Fig. 2.—The rudimentary anatomic contour is formed with a V-shaped cut. The apex of the V is centered over the central areas of the posterior teeth.

Fig. 3.—The occluding of the two V-shaped occlusal forms allows the proper positioning of the holding cusps.

A premolar, or a molar having an opponent, is selected and its pattern is seated. This pattern is adjusted until there is enough space between it and the opposing tooth to provide occlusal thickness for the opposing pattern. The humming test is used to determine the necessary amount of space. The shaping of the patterns during all reductions should provide for the formation of a rudimentary occlusal anatomy. The converging cuspal inclines should form *V*-shaped central fossae (Fig. 2). These fossae should be centered within the circumference of the roots. Upper lingual cusps should occlude with the central fossae of the lower teeth, and the lower buccal cusps should occlude with the central fossae of the upper teeth (Fig. 3). The opposing tooth is fitted with its pattern which is adjusted until both patterns remain free of contact when the sibilants are enunciated. The same procedure is repeated on the other side with the aid of articulating paper. The remainder of the patterns are reduced to the vertical dimension of occlusion established by the first two patterns. The occlusal plane and curve of Spee are determined during this procedure.

Occasionally, it is found that a tooth has not been reduced sufficiently in its preparation. A ground-through (perforated) pattern indicates where further reduction of the tooth is necessary. The pattern may be left perforated, and the

necessary correction can be made on the die in the laboratory. The correction of the die is made with the pattern in position, and the ground-off portion of the pattern can act as a guide to the proper correction of the tooth in the mouth. This important problem is one of many which can arise and can be recognized and anticipated. The dentist can become familiar with his prescription and make decisions at a time when they are more readily verified in the mouth. Before proceeding to the second stage of grinding, it is wise to verify the vertical dimension of occlusion with the sibilant test and then to check for simultaneous, even contact when the jaws are in centric relation.

CONTACT IN CENTRIC RELATION

Simultaneous, even contact in centric relation can be tested by having the patient relax all of the closing and opening muscles of the mandible. The dentist then gently retrudes the jaw and swings it upward very slowly until the first slight contact is made. While closely observing the teeth, the patient is asked to close tightly.

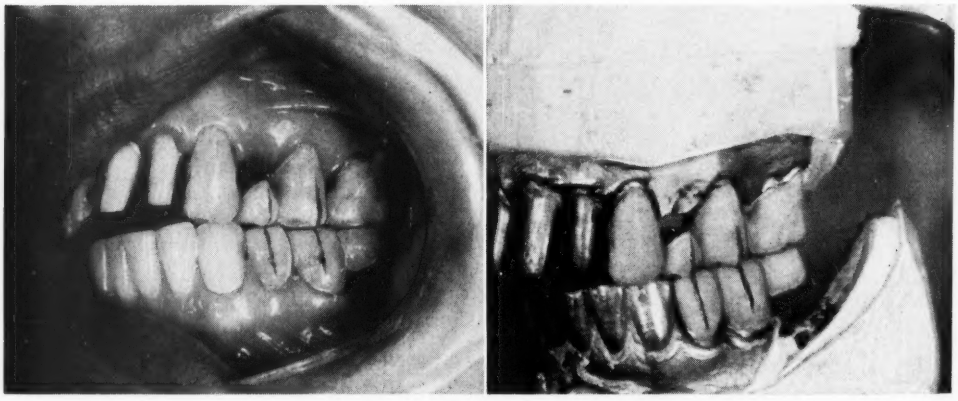

Fig. 4. Fig. 5.

Fig. 4.—The mandible is in a left lateral position. The patterns have been scored so that the scorings form a straight line.

Fig. 5.—The same scored patterns on casts mounted on the articulator with the mandible in left lateral position. The scorings coincide as they do in the mouth.

If there is any shift of the mandible after the first contact, however slight, it is because the first contact was premature. The same procedure is repeated, and the prematurity is marked with articulating paper and removed. The procedure is repeated until no shift takes place.

Second Grinding Stage.—The objectives of the second stage are: (1) to maintain the vertical dimension, (2) to eliminate all cuspal interferences in functional and in lateral and lateral protrusive movements, and (3) to determine the placement, size, and shape of the anterior teeth.

All reductions of interferences are made during voluntary, functional movements. An important precaution, which must be observed in the grinding in the second stage, is that of preventing the loss of the established vertical dimension. It

is necessary that the holding cusps and fossae are not reduced when the interferences are removed. Additional plastic probably will be needed to build out buccal cusps to provide adequate overhang to protect the cheek, or be added to a lingual cusp to provide continued support on the balancing side. The protrusive movements might indicate the need for more material to form a steeper curve of Spee. At no time should material be added which could reduce the interocclusal distance.

The anterior tooth patterns can now be shaped and characterized as to position and size. The form of the lip makes a definitive prescription for the anterior segment possible. With the lower jaw in a lateral protrusive position, and the buccal surfaces of the patterns in line, the surfaces of two or more opposing teeth may be scored with a disk (Fig. 4). When a similar movement is made on the articulator, the coincidence of the scorings should check the accuracy of the articulator mountings (Fig. 5).

SUMMARY

The use of the acrylic resin transfer pattern facilitates establishing an occlusion of the teeth based on physiologic needs. The maxillomandibular relationships are recorded more easily and coordinated with the functional requirements of the oral mechanism. This technique is independent of maxillomandibular relationships which existed prior to restorative procedures. The transfer pattern makes possible the determination, registration, and transfer of the various maxillomandibular relationships. It permits verification of the accuracy of the articulator mounting and thus reduces the degree of error in the laboratory work.

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THE REVERSE PIN-PORCELAIN FACING

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THE INTENT OF THIS article is to discuss the various types of porcelain facings available for fixed bridge prosthodontics and to evaluate a new type of porcelain facing for this purpose. However, it is imperative to emphasize the importance of making a comprehensive diagnosis before instituting any type of dental service. The success or failure of all dental procedures is predicated on an intelligently planned method of treatment which is only possible after a thorough roentgenographic, functional, and clinical diagnosis has been made.

FACINGS AVAILABLE FOR PONTICS

A well-engineered fixed partial denture restoration is the finest means of tooth replacement wherever it can be used. Because of esthetics, the replaced tooth in the form of a pontic must be supplied with a facing of porcelain or the much less desirable acrylic resin plastics.

The plain long-pin type of porcelain facings, to which can be baked a gingival area of porcelain adapted for tissue contact and subsequently glazed for tissue tolerance, are available (Fig. 1, *A*). A modification of the long-pin facing, the "Pin-Pontic," is manufactured with a gingival portion of porcelain which is intended to be ground and fitted to ridge contact and subsequently polished or "overglazed." The interchangeable type of porcelain facing is in common use (Fig. 1, *B*), and is supplied with a standardized metal backing with a male lug which fits into a female groove on the lingual aspect of the facing. This facing and backing is also available with a gingival baked tip (Trupontic) which can be ground to fit the edentulous ridge and either polished or "overglazed."

It is in rare instances when a facing of any type can be made to harmonize with esthetic and occlusal requirements without alteration. When any facing has been "customized" to conform to the environment for which it is intended, it is fallacious to assume that it is "interchangeable" in the true sense of the word.

Facings which fracture do so because of some mechanical or occlusal discrepancy, and they will continue to fracture, no matter how many times they are replaced, unless the cause for fracture is eliminated. The logical approach for avoiding fractures of facings lies in the proper biomechanical design in the original fabrication of the gold and porcelain pontics.

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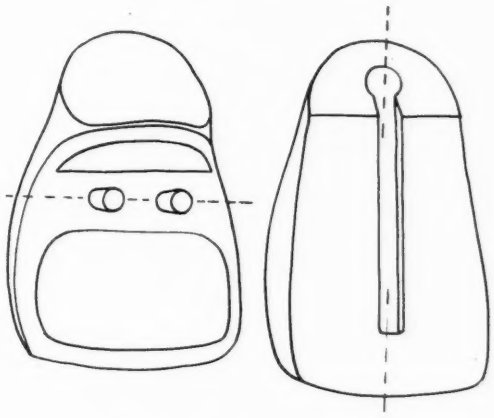
DISADVANTAGES OF PORCELAIN FACINGS

The long-pin porcelain facings, interchangeable porcelain facings, and their modifications have certain disadvantages:

1. The pins in facings necessarily incline lingually, and the teeth in the opposing arch often interfere with the position of the pins to such an extent that the pins must be shortened, making them virtually worthless for retention. This is especially true where the distance between the ridge and the opposing occlusion is very small, making it impossible to use pin facings (Fig. 2).

2. The color harmony is ruined by grinding away the gingival aspect of the facing in order to place the facing as far gingivally as possible to avoid the opposing tooth interference and gain pin length. The color distribution is changed by destroying the gingival yellows and oranges, thereby displaying more incisal color than was originally intended (Figs. 3 and 4).

Fig. 1.



A. *B.*

Fig. 2.

Fig. 1.—Potential fracture lines in porcelain facings. *A*, Pin-Pontic. *B*, Interchangeable.
Fig. 2.—The occlusion interferes with the effectiveness of pins for retention of the facing.

3. The anatomy of the facing which was suitable at the time of selection may be destroyed by grinding on the gingival aspect of the facing to obtain a more favorable pin length and pin placement.

4. The process of fusing porcelain around metal pins in the manufacture of facings tends to create minute fracture lines in the porcelain because of the difference in the coefficient of expansion between the metal and the porcelain. This creates a potential line of cleavage in the region of the pins, and pin facings rarely fracture except in the region of the pins (Fig. 1, *A*).

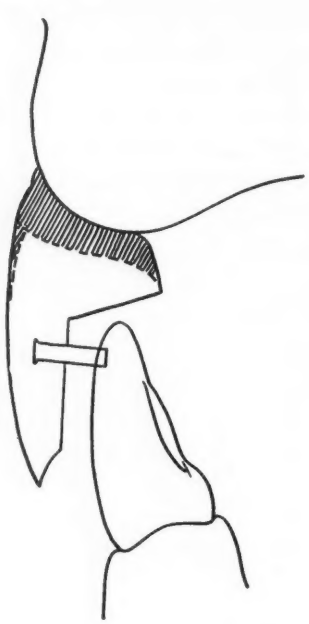
5. A limited amount of retention is provided by the two pins, and the position of this retention is fixed by the position of the pins as supplied by the manufacturer. It would be desirable to have facings with multiple areas and positions of retention according to the size and shape of the facings (Fig. 5, *A* and *B*).

6. It is difficult to overlap anterior facings without displaying the gold backings of the lapped pontics due to the flat backs of the available facings (Fig. 6).

7. The limited selection of molds and shades available is one of the greatest disadvantages in the use of anterior porcelain facings in fixed partial denture pontics.

8. The "interchangeable" type of facing is subject to fracture. The lingual groove can be likened to a "score" mark in a block of ice previous to its separation or cleavage by wedging (Fig. 1, *B*).

Fig. 3.



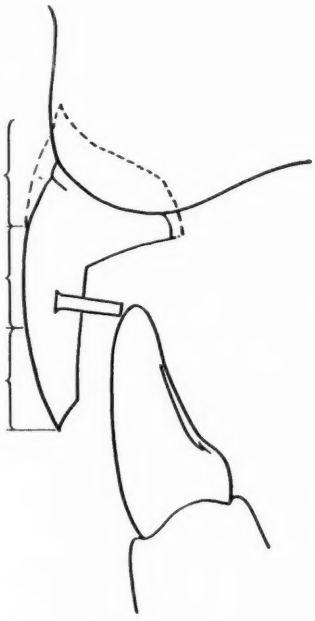
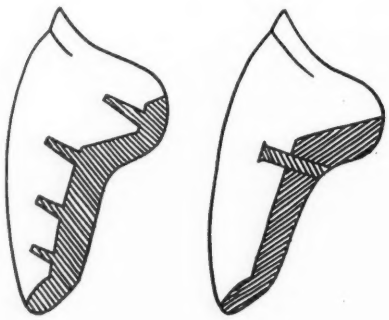


Fig. 4.

Fig. 3.—Porcelain added to the cervical end of the facing for tissue contact.

Fig. 4.—Grinding from the cervical end of the facing shows more incisal color than was intended.

Fig. 5.



A. *B.*

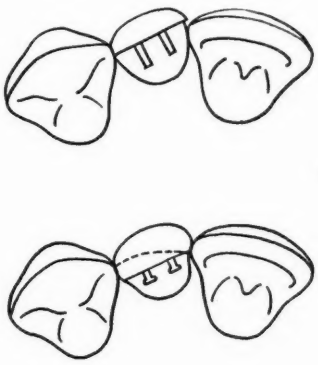


Fig. 6.

Fig. 5.—Pin retention for porcelain facings. *A*, Multiple pins extending into the facing are more efficient than *B*, two pins extending into the backing.

Fig. 6.—*Above*, Pin facings expose gold when the pontics are rotated. *Below*, A denture tooth is rotated. The dotted line indicates the position of the concealed reverse pin backing.

ACRYLIC RESIN FACINGS FOR FIXED PARTIAL DENTURE PONTICS

There are many shortcomings and failures in the use of acrylic resins as a facing material in fixed partial denture pontics, even though this material has been widely used. This material has been used for facings because:

1. Its manipulation is easy, and relatively fine-appearing pontics can be created by a process of molding the resin around a metal framework.

2. Proper molds and, to a lesser degree, shades can be attained by simple procedures.

3. Retention for acrylic resin facings can be attained under conditions that are unsatisfactory for available porcelain facings.

4. Some commercial dental laboratories dictate the use of this material because it is easier to manipulate the moldable resins and, therefore, less time consuming and, consequently, economically more sound for the laboratories.

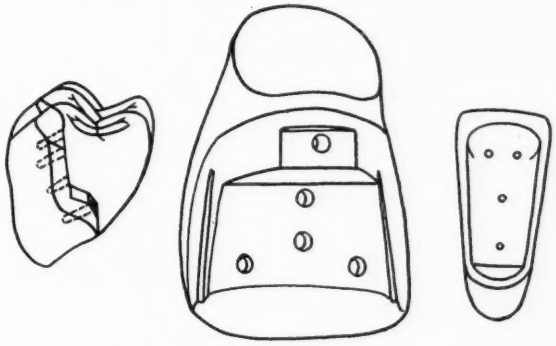


Fig. 7.—Reverse pin-porcelain facings made from denture teeth.

It is regrettable that dentists are forced to use acrylic resins possessing the inferior physical characteristics which are inherent in these materials. Some of these unfavorable characteristics are as follows:

1. It is a material with poor wearing qualities because of its softness.

2. There is a lack of bonding between the resin materials and metal backings or framework.

3. These materials lack dimensional stability due to moisture absorption, and they consequently change color, especially in the thinner facings.

4. The acrylic resins are inherently unclean when used in the oral cavity if they contact the gingival tissues and other areas of stasis.

In spite of the adverse qualities of this material, there are occasions when acrylic resins must be used because of the shortcomings of available porcelain facings.

Many attempts to modify porcelain facings for fixed partial denture pontics have been made. Anterior denture teeth have been modified by removing the two pins so that corresponding pins on the backings could be cemented into the pin holes. This procedure has not been entirely satisfactory since the pin holes were

too large and were positioned too close to the gingival end of the tooth. However, the great selection of molds and shades of available denture teeth can now be successfully adapted and utilized for porcelain facings for fixed partial denture pontics because of a new technique by which either anterior (pin) or posterior (diatoric) denture teeth may be used. Facings made possible by this technique are termed "Reverse Pin-Porcelain Facings" (Fig. 7).

THE REVERSE PIN-PORCELAIN FACING FOR PONTICS

A porcelain denture tooth with satisfactory shading and morphology is selected. It is adapted to the working cast, either with or without a gingival tip of baked porcelain. The tooth is properly beveled and hollow ground in the incisal area and otherwise prepared for the waxing of the backing. The size and shape of the prepared facing is studied, and 3 to 6 or 8 parallel holes are drilled in its lingual aspect. The positions of these holes is dependent upon the size and thickness of the porcelain. The greater the area over which these holes can be spaced, the more retention and support can be afforded to the porcelain facing by the backing.

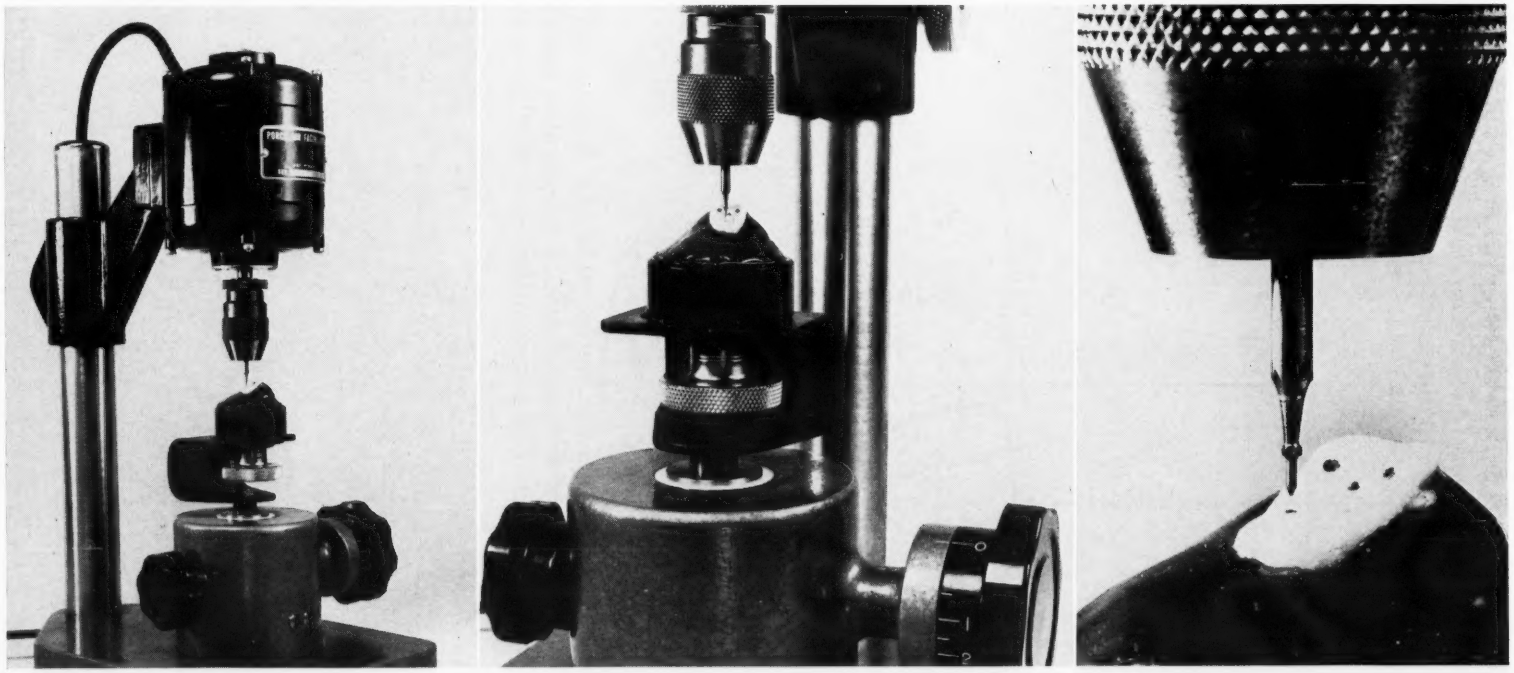
Holes of a small diameter will permit the use of a greater number, and they can be drilled to a lesser depth because of the relationship of their diameter to their depth. In order to gain the maximum of frictional retention between the pins in the metal backing and their respective holes in the porcelain, the holes should be drilled in the facing to a minimum depth of twice their diameter. Three and one-half or four times their diameter is the optimum relationship of depth to diameter.

Holes varying in size from that of a No. 700 fissure burr to holes accommodating wire or nylon bristles of 27 or 28 gauge are used. The drilling of these holes is simple and not time consuming if the proper equipment is employed. In the development of this facing many problems were encountered, but these were automatically solved by the use of a specially designed precision drill press (Fig. 8).

At present, the technique has been standardized to use holes which will accommodate pins of 0.018, 0.020, and 0.022 of an inch in diameter in the metal backing. However, the size, depth, position, number, and distribution of the holes may be varied according to the morphology of the porcelain facing.

The holes should not be drilled in a straight line, either in the vertical or horizontal direction, either of which may tend to create lines of cleavage such as exist in the currently available facings for pontics. The holes should be drilled in a random pattern depending upon the thickness of the porcelain in the drillable area (Fig. 9).

The parallel holes should be drilled to incline in a gingival direction, thereby providing greater bulk of porcelain which is especially advantageous in the incisal or occlusal areas. The weakness of large areas of unretained porcelain incisally and gingivally to the pins in pin facings is easily overcome in the reverse pin-porcelain facing by drilling holes for pins in these areas to create a multiplicity of retention (Fig. 5). A metal backing cast for a facing prepared with parallel holes provides precision retention.



A. *B.* *C.*

Fig. 8.—*A*, The porcelain facing drill press. *B*, The chuck and ball-bearing cam lift. *C*, The ground down denture tooth is mounted in jewelers' hard shellac on the holder. The cutting tool is made from a carbide dental burr.

Another advantage of drilling the holes so they are inclined in a gingival direction is that the backing pattern may be withdrawn from the facing in an incisal or occlusal direction rather than against these margins. This makes it possible to create a fine finished gold and porcelain margin in these areas.

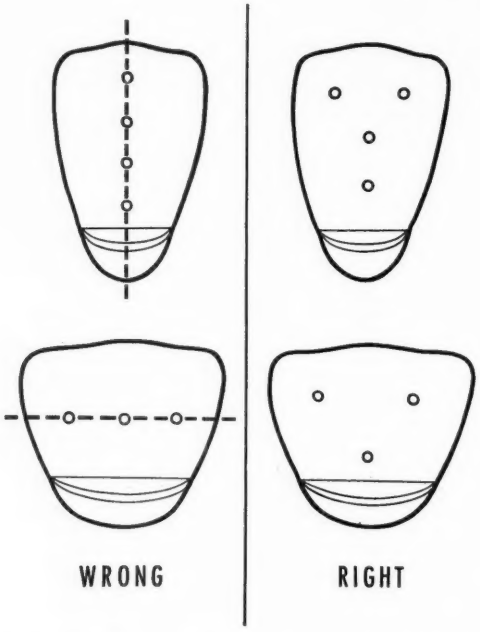


Fig. 9.—Incorrect and correct locations of the retention pin holes.

FUNDAMENTALS REQUIRED IN DRILLING PORCELAIN

The drilling of holes in porcelain is *simple,* but *precise* provided the following fundamentals are adhered to and the proper type of equipment is employed:

1. True running rotary cutters made from discarded carbide fissure burrs with bibeveled cutting edges are used as drills.

2. The facing to be drilled must be mounted in a holder by means of jewelers' hard shellac which is subsequently mounted on the platform of a drill press. By mounting the facing in this manner, precise small parallel holes may be drilled with a delicate cutter without any danger of fracturing the brittle carbide drill.

3. A true running precision drill press is essential for drilling small holes in a substance as hard as porcelain with a cutter as small and brittle as tungsten carbide. The spindle or motor shaft, to which a true running chuck holding the carbide drill is attached, must be devoid of either end-play or side-play. A rotating speed of 3,000 to 3,400 r.p.m. seems to be the most satisfactory.

The "feed" of the drill to the porcelain must be very delicate. A smooth ball-bearing cam lift is preferable to that of a rack and pinion or screw drive.

Unfortunately, small commercial precision drill presses fulfilling the desired specifications could not be located. Therefore, it was necessary to design an adequate drill press (Fig. 8, *A, B,* and *C*). True holes of varying sizes can be drilled,

with properly formed cutters, in hard and unyielding porcelain in a matter of 5 to 10 seconds per hole with this drill press.

4. A cutting lubricant or coolant must be employed in the drilling process and, while several types may be employed, a mixture of equal parts by volume of olive oil and kerosene is satisfactory.

TYPES OF BACKINGS FOR REVERSE PIN-PORCELAIN FACINGS

Two types of backings are employed in the fabrication of reserve pin-porcelain pontics.

In the large central incisor and molar facings, parallel tapered holes are drilled to which the backings and pins are waxed as a single unit (Fig. 10, *A*). Because of the taper and parallelism of these holes, the wax backing with its wax pins is readily removed from the facing without danger of fracturing the pins.

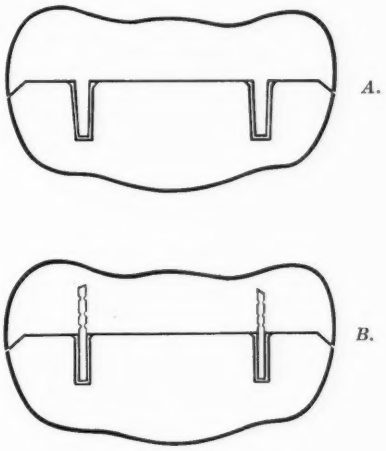


Fig. 10.—Types of backings: *A*, One-piece backing and large pins. *B*, Backing cast around notched pins or nylon bristles.

The majority of the facings used in fixed partial dentures have a relatively small bulk of porcelain, especially after they have been prepared for waxing by hollow grinding the incisal or occlusal aspects and by beveling the other margins. As a result, most reverse pin facings are fabricated by drilling parallel straight-sided holes into their lingual aspect which vary in diameter from 0.022 of an inch down to 0.018 of an inch (Fig. 10, *B*).

The diameter of the holes is determined by the size of the facing. If pins of 0.018 inch in diameter are to be used, clasp metal wires or nylon bristles of such a size are placed in their respective holes, and the waxing of the backing is completed.

If metal pins are to be used, the ends projecting into the backing should be roughened or nipped slightly with a wire cutter to afford mechanical retention of the casting to the metal pins (Fig. 10, *B*).

Backings waxed to nylon bristles,* which are subsequently burned out, have

*(Tynex) Manufactured by Du Pont in a great variety of sizes.

resulted in excellent castings. This is currently the preferred method of making the pin patterns for the backings.

Due to the accuracy with which the holes can be drilled, it is simple to drill them of a size that creates a very close tolerance with the diameter of the nylon bristle or wire. Obviously, this would create a subsequent hazard in cementing the backing to the porcelain facing because of the hydraulic pressure created by the cement. To prevent this problem, the holes are drilled from 0.002 to 0.003 of an inch larger in diameter than the wire or bristle used, thereby allowing a clearance of from 0.001 to 0.002 of an inch on each side of the cast or wrought metal pin.

Although cast pins 0.018 of an inch appear small in diameter, the safety factor of strength is more than sufficient when the shear strength of such short lengths of metal pins is considered, especially when four or more pins are employed.

PREPARATION OF TUNGSTEN CARBIDE DRILLS

The preparation of the tapered carbide drills is simple. A fine grit, 3/4 or 7/8 inch diamond-separating disk, is rotated on each side of the end of a small, discarded, tapered fissure tungsten carbide burr, in such a manner as to create a bibeveled drill (Fig. 11). The angle of this bevel should be about 30 degrees. This shaping should be done with the aid of magnification.

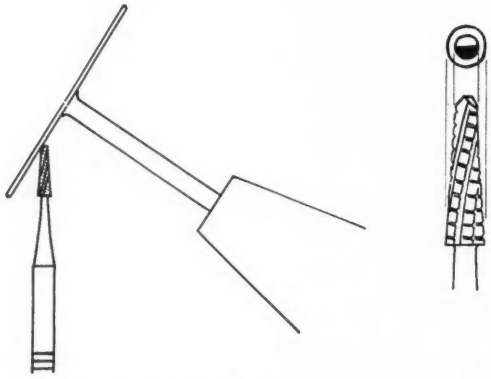


Fig. 11.—The end-cutting bibeveled drill is made from a carbide burr. *Left,* The bevels are made with a diamond disk. *Right,* The blades of the tapered burr are allowed to remain.

The fluting on the side of the burr must be allowed to remain so that, in the drilling process, it will create a clearance and a taper as the burr cuts on its end and enters the porcelain (Fig. 14, *A*). The creation of this clearance is important because it will prevent the sides of the drill from binding against the facing with a consequent fracture of the porcelain.

The preparation of carbide drills for drilling holes of 0.022 of an inch and smaller is done in an entirely different manner than the preparation of the drills for tapered holes.

If a wire or nylon bristle of 0.020 of an inch is to be employed, a micrometer or similar measuring device is set at approximately 0.023 of an inch (Fig. 12). A

fine grit diamond disk similar to the one used for bibeveling the tapered fissure burr is mounted in a dental engine handpiece, and the carbide burr from which the drill is to be made is mounted in the chuck of the drill press (Fig. 13, *A*). With the burr and diamond disk revolving in opposite directions, the disk is held against the burr and reduced in diameter until it measures approximately 0.023 of an inch with the preset micrometer (Fig. 12).

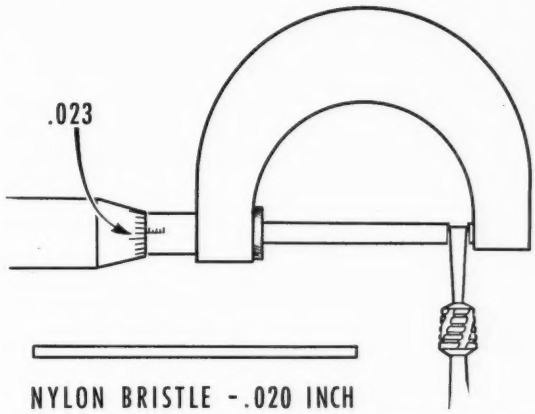


Fig. 12.—The nylon bristle and the reverse tapered drill properly sized for drilling the holes in the porcelain facing.

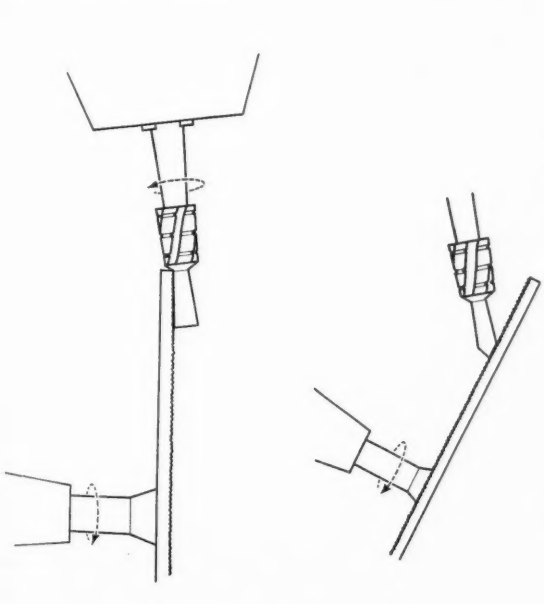


Fig. 13.

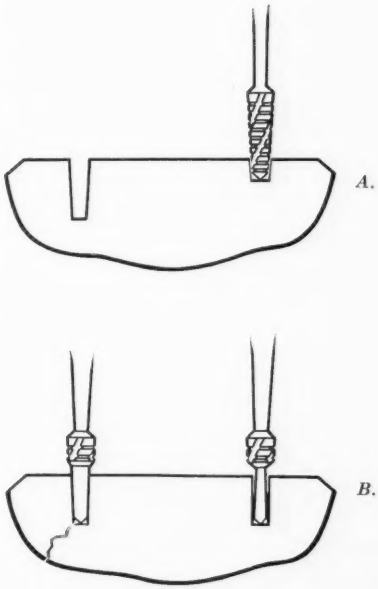


Fig. 14.

Fig. 13.—*A*, The reverse taper is made by a rotating diamond disk while the carbide burr is rotating in the chuck of the drill press. *B*, 30 degree bevels are made with the diamond disk.

Fig. 14.—*A*, The fluting on the burr provides clearance for the coolant and the cut porcelain. *B*, The reverse taper provides clearance and prevents fracture of the facing.

It is essential that this drill does not bind in the facing while cutting the porcelain. Therefore, a clearance is provided in the drill by preparing it with a *reverse taper* of 1 to 2 degrees.

After the burr is reduced to the proper diameter and reverse taper, it is sharpened by bibeveling the end to an angle of approximately 30 degrees using the same diamond disk (Fig. 13, *B*).

The finished drill must have the following characteristics: It must have a slight reverse taper in order that it will clear itself in the drilling process and not bind in the porcelain with a resulting fracture of the porcelain or drill (Fig. 14, *B*). It must not be over 2.5 to 3 mm. in length for maximum strength. It must have a bibveled sharp cutting edge of approximately 30 degrees (Figs. 15 and 16).

Fig. 15.

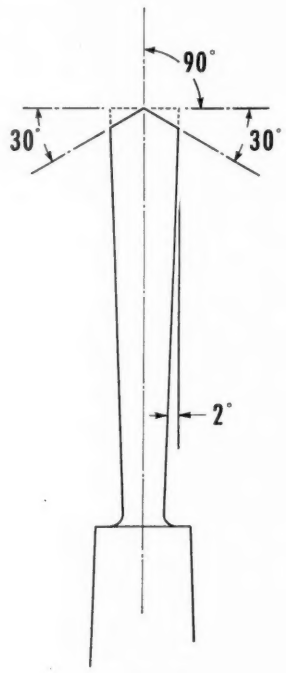


Fig. 16.

Fig. 15.—A properly formed cutting tool.
Fig. 16.—The correct bevel angulations.

Magnification with binocular loupes probably will be required by the average operator in order to produce these drills, and while the detailed description in fabricating them seems involved, the actual procedure is simple, requiring not over 5 to 10 minutes for the operation. It is convenient to select the desired diameters of wires or nylon bristles and place them in suitable separate compartments in a box, and to prepare several drills of the proper size for each and place them in their respective compartments to be used as needed.

STEPS IN FABRICATION

The shade and mold of tooth to replace the missing central incisor is selected prior to the preparation of either abutment tooth (Fig. 17). Since the technique permits the use of anterior denture teeth, the selection of a porcelain tooth which conforms to the required mold and shade is greatly facilitated. There are some natural teeth, however, with such peculiarities of shading and morphology that they cannot be matched by any available denture teeth or facings. In these cases, it is necessary to bake a special facing with a porcelain tip reproducing the required shade and anatomy. This facing can be tried in the mouth and when it conforms to the requirements of esthetics, it can be prepared and drilled for the construction of a reverse pin-porcelain facing pontic.

The selected denture tooth (Fig. 17, *A*) is ground and repeatedly tried in the edentulous area in the patient's mouth until it assumes the proper incisogingival

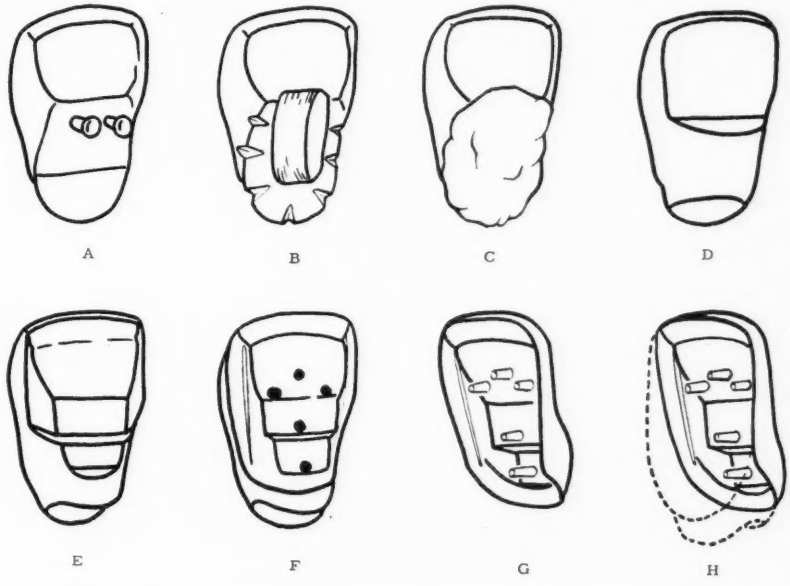


Fig. 17.—The steps in fabricating a reverse pin-porcelain facing for a central incisor. *A*, A denture tooth of the appropriate size, shape, and color is selected. *B*, The pins are ground off, and the lingual surface is ground to fit the edentulous area. *C*, Porcelain is added to the cervical end. *D*, The lingual surface is shaped to fit the available space. *E*, The lingual surface is ground to provide space for adequate bulk of gold in the backing. *F*, The retention holes are drilled into the porcelain. *G*, The backing is waxed. *H*, The backing is cast and placed on the facing.

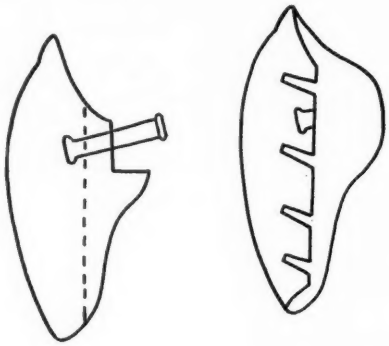
position for color distribution. This control over incisogingival color harmony without the interference of pins on the lingual surface is an important advantage in the technique.

After the porcelain tooth has been ground and oriented to fulfill the esthetic requirements, it is laid aside. The abutment teeth are prepared, patterns for the castings are made, and the castings are seated on the abutment teeth. Impressions and working casts are made. The casts are mounted on an articulator for the laboratory procedures.

LABORATORY PROCEDURES

The prepared porcelain tooth is positioned on the working cast with wax, and a stone core is made on the labial surface of the tooth and abutments.

If highly polished gold is to contact the mucous membrane in the edentulous area, the lingual pins of the denture tooth need not be completely removed, but merely ground flush with the lingual surface of the porcelain. The facing is ground to provide for lingual clearance for an adequate thickness of metal for the backing. The incisal area is hollow ground and the edges beveled preparatory to drilling the retention holes (Fig. 18, *A* and *B*).



A. *B.*

Fig. 18.—*A*, The lingual surface of the denture tooth is ground to provide space for the gold backing. *B*, The incisal edge is hollow ground, and the pin holes are drilled.

If a baked porcelain tip is to be used, the pins are ground completely away until there is no vestige of metal left in the porcelain (Fig. 17, *B*). The edges of the porcelain in the linguogingival (ridge-lap) area are scored. Then, the facing is placed in a suitable holder and medium-fusing S. S. White porcelain is applied. On this first application of porcelain, the ground-out area and the scored edges are covered with the medium-fusing porcelain and baked to a high biscuit texture (Fig. 17, *C*).

The facing is again placed in a holder, and a second application of medium-fusing S. S. White porcelain is applied. This application is overbuilt, and baked to a high biscuit. The facing with the oversized tip of baked porcelain is ground to fit the edentulous area on the working cast with the aid of the stone core, and the gingival surface is shaped to the desired contour. This ground-in pontic is returned to the porcelain furnace and fired to a high glaze (Fig. 17, *D*).

The facing with its baked gingival tip is prepared for waxing of the backing by grinding the lingual surface to provide for a sufficient space for the backing and otherwise prepared by hollow grinding the incisal area, beveling the edges, etc. (Fig. 17, *E*).

The prepared facing, either with or without the baked porcelain tip, is cleaned with chloroform and slightly warmed in a Bunsen burner. The mound of shellac on the facing platform is heated over a Bunsen burner. The warmed facing is imbedded in this softened shellac at an angle which positions the incisal portion at

a higher level on the mounting platform than the gingival portion (Figs. 19 and 8 *A, B,* and *C*). This angulation of the facing places its lingual surface at a tangent to the drill and permits a greater bulk of porcelain to be drilled in the thin incisal region (Fig. 19).

With a sharp-pointed pencil, the positions of the holes to be drilled are marked on the lingual surface of the mounted facing (Fig. 8, *C*).

The platform holding the facing is attached to the drill press with the previously described specifications, and a carbide drill of suitable size, dependent upon the facing size, is placed in the chuck.

A small, pointed brush charged with the coolant (equal parts of kerosene and olive oil) is repeatedly applied to the facing during the drilling process. The facing and drill must *never* be allowed to become dry during the drilling procedure.

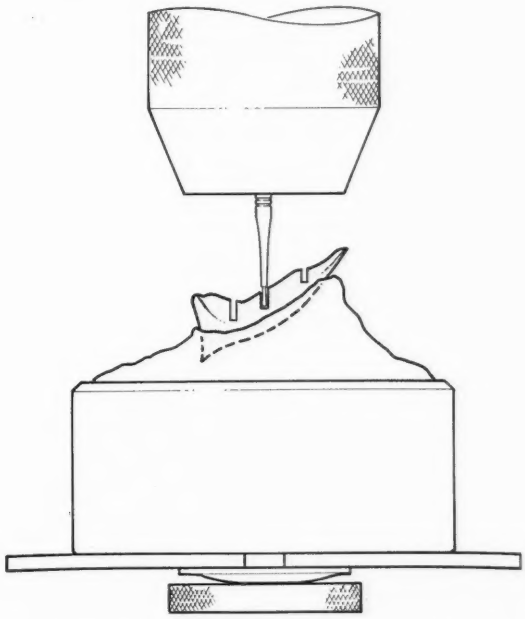


Fig. 19.—The retention pin holes are drilled so they incline toward the thicker porcelain at the cervical end of the facing.

The facing platform is placed in a horizontal position so that one of the pencil marks coincides with the end of the drill, and it is locked in this position. The drill press is started, and the feed knob is used with a *short, intermittent, delicate action with a constantly repeated application of the coolant.* If the drill does not cut properly, the bibeveled edge should be examined under magnification; it is either improperly beveled or it is dull. A sharp cutter will drill three or four holes, at which time it must be resharpened.

The facing platform is repositioned and locked in the horizontal positions necessary for drilling the other desired retention.

If a facing with a gold saddle is to be used, the holes should be drilled into the porcelain incisally and gingivally to the remnants of the metal pins of the denture tooth (Fig. 18, *B*), and not into these remnants.

COMPLETION OF THE REVERSE PIN PORCELAIN AND GOLD PONTIC

The drilled facing (Fig. 17, *F*) is removed from its mounting platform by cutting a sufficient amount of shellac away from the facing with a sharp knife so the facing can be pried off its mounting. All remnants of shellac should be cleaned from the facing with chloroform.

Short lengths of nylon bristles of the predetermined diameter are cut with a sharp razor blade and placed in the holes of the lubricated facing so they protrude about 3 mm. The ends of these protruding bristles are melted into small balls or knobs by touching them with a well-heated wax spatula. The knobs provide retention for the bristles in the wax pattern for the backing. A thin layer of inlay casting wax is melted on the lingual surface of the facing and around the protruding ends of the bristles.

The facing with its partially waxed backing and index core is placed on the working cast, and the waxing of the backing is completed in the usual manner. The completed wax backing is sprued as nearly in line with the angle of the pins (bristles) as possible. A small piece of sticky wax is melted on the dried labial surface of the facing for use as a handle in removing the facing from the waxed backing. Then the pattern for the backing is invested, processed, and cast.

After the casting is made (Fig. 17, *G*), it is cleaned thoroughly and examined for minute imperfections or bubbles which must be removed mechanically. It is chemically or electrolyticly etched *before* attempting to seat the facing on its cast backing.

Before seating the facing on the casting, the sharp edges around the drilled holes must be slightly chamfered. This is done by using a round carbide burr, somewhat larger than the diameter of the holes, in a dental engine handpiece. No coolant is necessary while the burr is revolved against the edges of the holes at a medium rate of speed for 2 or 3 seconds to accomplish the desired results (Fig. 20).

This slight chamfering of the edges of the holes prevents the fracturing of small pieces of porcelain from around the holes in case the backing is not withdrawn from the facing in a line parallel with the pins (Fig. 20, *B*).

After the backing has been finished against the facing, it is necessary to attach pieces of sticky wax on the lingual surface of the backing and on the labial surface of the facing to act as handles in order to separate the facing from the backing.

The completed pontic (Fig. 17, *H*) and abutments are related in the desired manner and soldered. In cementing the porcelain facing to the backing, it is necessary that the cement reaches the bottom of the pin holes. To facilitate this, part of the cement is mixed to a slightly thinner consistency than is required for the final cementation. This cement should be mixed slowly and in such a manner as to retard its initial setting. A small amount of the thin mix of cement is placed on a root canal reamer which has a portion of its sharp end removed. The reamer is introduced into each hole and spun in a counterclockwise direction. Centrifugal

force will carry the cement to the bottom of the holes in the facing. The remaining cement is mixed to the usual consistency and placed on the facing and backing, and the facing is seated into position.

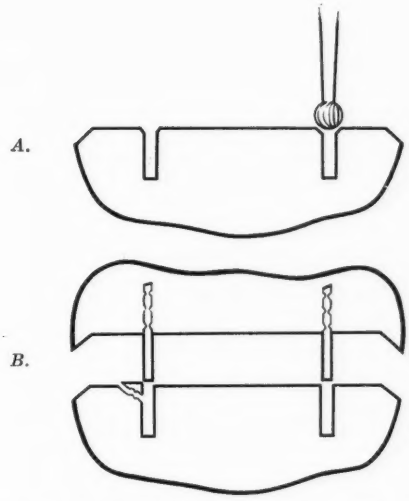


Fig. 20.—*A*, The pin holes are beveled by a carbide burr to prevent fractures. *B*, A fracture resulting from the failure to bevel the pin hole.

POSTERIOR PONTICS

While the reverse pin-porcelain facing was primarily developed to overcome the shortcomings of the available facings for anterior pontics, the technique is applicable to the construction of posterior pontics. Similar problems to those of the anterior region exist also in the posterior region.

Many bicuspid and molar replacements present the problem of interference with the pins of orthodox pin facings by the opposing teeth. Prolonged absence of a bicuspid or a molar permits a narrowing of the edentulous space. These conditions make it difficult to use a pin type of porcelain facing. These problems are easily solved by the use of reverse pin facings.

In some situations, it is desirable to house a precision attachment or a dowel within the contour of a posterior pontic to provide direct or indirect retention for a removable partial denture. This becomes a difficult problem if a pin facing has been used because of the interference of the pins with the attachment. The reverse pin pontic overcomes this difficulty since the pins in the backing incline in a buccal direction.

Diatoric denture teeth can be used for constructing posterior reverse pin facings. The occlusal and lingual portions are removed by grinding, and the resultant incomplete facing is cored on the working cast. The remaining steps of baking a gingival tip, grinding the facing for ridge adaptation, glazing, preparation for waxing of the backing, drilling the retention, etc. are carried out in the same manner as for the construction of the central incisor facing (Fig. 21).

A newly manufactured "side-grooved" tube tooth* is also adaptable for the fabrication of the posterior reverse pin facing. An oversized tooth is adapted to the ridge area by grinding, and the occlusal and lingual contours are also removed, thereby creating a facing with a porcelain tip without using the baking process. Because of the excellence of the vacuum-fired, high-fusing porcelain in these teeth, they can be contoured and polished easily. The facing is completed by drilling the retention holes and constructing a backing in the same manner as for the anterior facing.

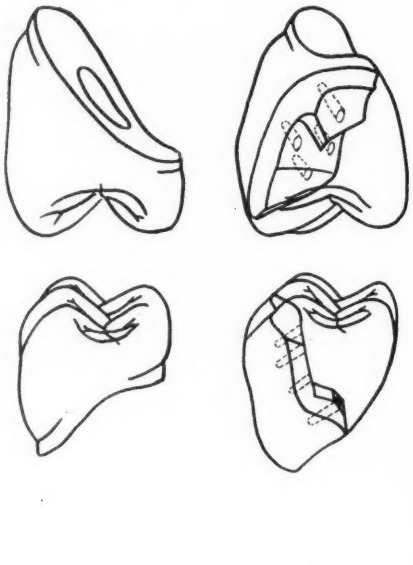


Fig. 21.

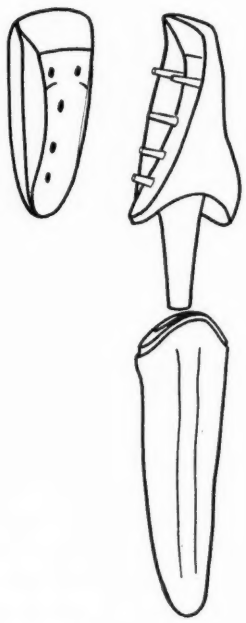


Fig. 22.

Fig. 21.—The design of posterior pontics fabricated from diatoric denture teeth.

Fig. 22.—A reverse pin-porcelain facing for a dowel crown.

MODIFICATIONS

The reverse pin-porcelain facing may be used satisfactorily for constructing a porcelain and gold crown with a gold stump housed in the root canal of a properly treated pulpless tooth (Fig. 22). This same modification can be used for restoring the crowns of badly broken down vital teeth with full gold veneer restorations which permit the use of a porcelain facing of sufficient thickness for drilling the holes. These modifications are feasible because of the relative simplicity of drilling the holes which are extremely small in diameter (0.017 inch), thus requiring the minimum of depth for retention.

*Manufactured by the Columbus Dental Manufacturing Co., Columbus, Ohio.

SUMMARY AND COMMENTS

A simple and precise method of drilling small parallel holes in porcelain has been described. The crown and bridge prosthodontist can make use of this method of creating porcelain facings for fixed partial denture pontics by modifying any prefabricated porcelain denture tooth or specially baked porcelain facing. This has obvious advantages in fulfilling esthetic and mechanical retention requirements of pontics.

The reverse pin-porcelain facing may be used equally well for anterior and posterior pontics. Since a far greater number of posterior teeth than teeth in the anterior region are restored by fixed restorations, the reverse pin-porcelain facing fulfills a real need.

The basic biomechanical principles, as applied to porcelain and gold pontic design, must be adhered to in the use of the reverse pin-porcelain facing. This must include an adequate and unyielding gold backing protection for the porcelain facing, but it does not necessarily require an undue display of gold.

Consultation with engineers relative to the design and construction of the reverse pin-porcelain facing has elicited enthusiastic and favorable comments concerning its merits in relation to other types of available porcelain facings.

Tests of a large number of drilled porcelain facings placed in a low-surface tension aniline dye for seven days showed no evidence of cleavage or of fracture lines created by the drilling process. Examination under magnification demonstrated the holes to be true and well machined with a complete lack of imperfections.

Any difficulty encountered in the process of drilling into the porcelain is due to a violation of some phase of the technique. Careful adherence to the technique will assure success in the creation of these porcelain facings.

70 North El Molino Ave.
Pasadena 4, Calif.

OBSERVATIONS ON THE USE OF THE ULTRA HIGH-SPEED AIR TURBINE HANDPIECE

ROBERT W. FISCHER, D.D.S.
Cleveland, Ohio

THE USE OF AN air turbine handpiece, operating at speeds of about 250,000 r.p.m., is quite a radical departure from traditional procedure, and many questions naturally arise about it. Is it difficult to adapt to these high speeds? What are the reactions of patients to it? How does it affect the dentist? Is it really so different?

For the dentist who had previously been operating with rotational speeds no higher than 25,000 r.p.m., the ultra high-speed handpiece is a thrilling experience. To be able to remove tooth structure as quickly as one could desire without heat, vibration, or tension is a delight. For those of us who spend a large part of each day drilling on tooth structure, this formerly difficult task becomes simple and almost pleasant.

The patient is immediately aware of the lack of vibration and the freedom from heavy pressures from the cutting instrument. With the routine use of local anesthesia which has substantially eliminated pain during operative procedures, it has been vibration and pressure which have continued to make operative dentistry unpleasant. Now, after experiencing tooth reduction with the air turbine handpiece, patients invariably say that they no longer dread the next visit.

Aside from the reduced unpleasantness of the new cutting instrument, the most gratifying feature is the fact that better dentistry can be performed. There no longer is any reason to settle for anything less than perfect preparations. It is so easy to have definite line angles, precise shoulders, and adequate tooth structure removal that it would be folly to have less.

I have been asked, "What percentage of the time is the air turbine handpiece used?" I now use the conventional handpiece speeds only (1) for slices on the mesial and distal surfaces, using the straight handpiece with a disk; and (2) for the removal of that last bit of decay in very deep cavities, when there is a possibility of a pulp exposure.

Both carbide burs and diamond points are used with the air turbine handpiece. However, a nice feature is that a very limited armamentarium is required.

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Only small instruments are used because, at such high speeds, any instrument with a large outer circumference would develop an uncontrollable torque. Furthermore, even the slimmest of cutting points removes tooth structure so fast that it is unnecessary to resort to the cumbersome sizes.

The speed with which preparations can be made at the ultra high speeds borders on the fantastic. Occlusal and gingival cavities can be prepared in a matter of seconds. Two and three surface preparations may take a minute or two. For the dentist who makes full crown preparations for rehabilitation work, the ultra high speeds are especially effective. An entire quadrant may be prepared in a matter of minutes without the patient and the dentist feeling as if they have come through a major ordeal.

DISADVANTAGES

Some unpleasant features of ultra high speeds have become apparent in my experience. Drilling at these very high speeds is not painless. Far from that, it is more painful than drilling at lower speeds. Whereas, the dentist using the conventional rotational speeds can carefully peck away at the more sensitive dentine, gradually removing the last bits of decay, the air turbine user must attack these sensitive spots with undiminished speed, and it hurts. In fact, patients report a more intense, exquisite pain than that experienced at slower speeds. Also, the chilling action of the escaping air in itself is enough to be unpleasant.

For the patient who "prefers to get it over with" without a local anesthetic, the preparation can, of course, be done very quickly with the air turbine handpiece. However, because of the additional pain due to the high speeds, I find myself using more local anesthetics than before.

Although the air turbine handpiece is not inordinately noisy, it does emit a high-pitched whine. This is a little startling to the patient at first, and it is particularly unsettling to young children. This disadvantage usually can be overcome, however, if a moment is taken to demonstrate the noise to the patient before the handpiece is applied to the tooth.

Because of the great ease with which tooth structure is removed, and the corresponding decrease in tactile sense, there exists a slight danger of producing accidental pulp exposures. Consequently, in very deep cavities, I find it worth the extra precaution to revert to the use of the conventional handpiece to remove the final deepest bit of decay.

CONCLUSION

The air turbine handpiece is a device of great value to ease the burden of the dentist and to make good dentistry more bearable to the patient.

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FACTORS INFLUENCING THE ACCURACY OF SILICONE IMPRESSION MATERIALS

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THE SILICONE TYPE rubber impression materials have become increasingly popular. Their superiority over the Thiokols from the standpoint of esthetics, ease of mixing, and cleanliness make them worthy of consideration for many types of restorative and prosthetic dentistry. As with most newer dental materials, the many variables which influence their basic properties and clinical behavior have been only superficially studied.[1-4] The Thiokols, however, have been the subject of numerous investigations.[5-11] It was the purpose of this research to study certain of these manipulative factors not previously investigated.

PROCEDURE

Seven popular commercial silicone impression materials were studied (Table I). During the course of this research, the formulation of many of the brands was altered. The properties and handling characteristics for three of the materials were sufficiently different in the later batches to be considered separately from the earlier compositions, and they have been listed under the term "new." Code letters, not necessarily in the order listed, have been assigned to each brand. Due to the continued formula changes, it is not the purpose of this research to evaluate individual products but, rather, the general behavior of them as a group of materials.

The method of measuring the accuracy of the stone dies made from impressions treated in various ways involved the use of a master casting or ring fabricated on the original die. This technique has been used in other investigations.[6,9] The castings for the steel MOD Bureau of Standards die (Fig. 1, *a*) were seated on the stone dies under a load of one pound, and the distance by which the casting failed to seat was measured by a micrometer microscope. Failure of the master casting to seat properly on the stone die by 1 mm. represented a die approximately 0.22 per cent oversize. Since some of the dies were not oversize, but were actually undersize, another type of die was also employed (Fig. 1, *c,d*). A machined ring was used with a full crown-type preparation to determine whether the stone die was larger or smaller than the original. In the series where the influence of undercuts was studied the steel MOD die was used, but a gold casting was added to produce a definite undercut on the buccal and lingual surfaces (Fig. 1, *b*). The impression was made over this modified die. In addition to these models several single Dento-

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form teeth and two sets of four preparations for quadrant impressions were used. A minimum of six dies were made for each series of tests and the mean data are presented. Since the results on the MOD, full-crown, and technique teeth were closely parallel, only the data on the MOD are presented. Several representative photographs are shown to illustrate the magnitude of the changes observed.

The master dies were stored at 98°±2° F. before being used, and the impression and die were stored at that temperature in an atmosphere of 100 per cent humidity during curing of the material. Unless otherwise stated, the curing time for all materials was 10 minutes from the start of the mix. The manufacturers' directions for proportioning and mixing were followed carefully. The double-mix technique, using a separate syringe and tray material, was used with R & R Silicone, Elasticon, and SIR. The single-mix technique was used with all other brands. An adhesive was always used to bond the silicone to the band or tray.

Two sizes of unannealed copper shells were employed as trays for the single dies. A 13 mm. shell produced a thickness of 0.5 mm. of silicone between the die

TABLE I. THE PRODUCTS AND BATCH NUMBERS (IF AVAILABLE) OF SILICONE IMPRESSION MATERIALS USED IN THIS INVESTIGATION

BRAND NAME	BATCH NUMBERS	MANUFACTURER
Elasticon	752–PP–323–PP–415 744–PP–138–PP–266 752–PP–329–PP–416 763–PP–527–PP–631 782–PP–812–PP–690 783–PP–819–PP–854	Kerr Manufacturing Co., Detroit, Mich.
New Elasticon	X–26–254–1 X–26–255–2 X–26–256–1 X–26–256–2	
R & R Silicone		The Ransom and Randolph Co., Toledo, Ohio
New R & R Silicone	6400 64	
Lastic 55	0087 0297	A. Kettenbach, Wissenbach, Dillkreis/Hessen
DP Siligel	745, 748, 749	Dental Perfection Co., Glendale, Calif.
New Siligel	111–2 13–1 81–13 13–5	
SIR	9	Acralite Co., Inc., New York, N. Y.
Palatone Silicone Impression Paste		Central Chemical Laboratories, Chicago, Ill.
Justi Silicone Impression Material	12510	J. D. Justi & Son, Inc., Philadelphia, Pa.

and the shell while use of a 16 mm. shell permitted a 2.0 mm. layer of impression material, on both the MOD and the full crown preparations.

All dies were poured in Vel-Mix at a constant water-powder ratio, and the stone was allowed to set 24 hours before the master castings were tried on.

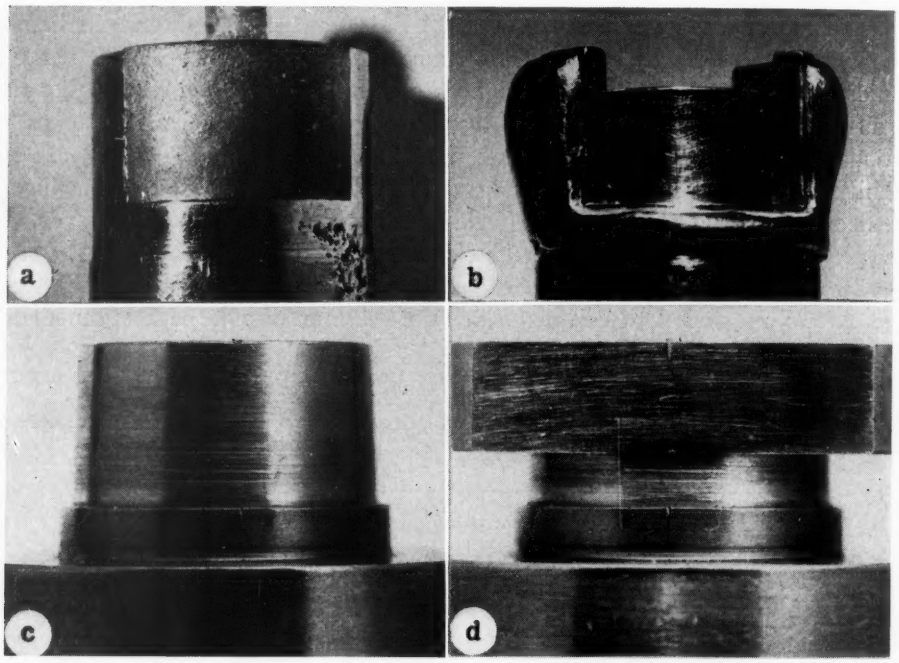

Fig. 1.—The dies used. *a*, The master casting fabricated on an MOD steel die. *b*, The casting added to an MOD die to produce undercuts on the buccal and lingual surfaces. *c*, The steel die simulating a full crown. *d*, The machined ring seated on a full-crown die. Failure of this ring to seat to this point indicated an oversized hydrocal model, while an undersized model could be measured by the ring seated below this point.

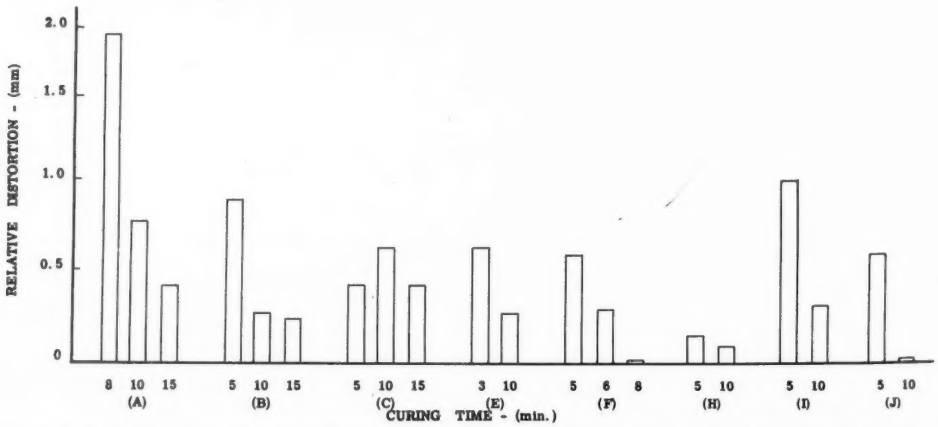

Fig. 2.—The effect of curing time (from the start of a mix until it was removed) for various silicones. The relative distortion represents the distance by which the master casting failed to seat under a constant load on the hydrocal die.

RESULTS

Curing Time.—The distortion at various curing times for each impression material can be seen in Fig. 2. This clearly indicates that, as with the Thiokols, adequate curing is essential. The minimum time required does vary with the material. For example, with brand A, a cure of 10 minutes is inadequate for maximum reproduction, although 10 minutes is sufficient for most of the other materials, and 8 minutes is adequate for brand F. Although the data presented in Fig. 2 involve only the straight-sided MOD steel die, the results parallel those obtained when preparations involving undercuts, outside the cavity preparation, were used.

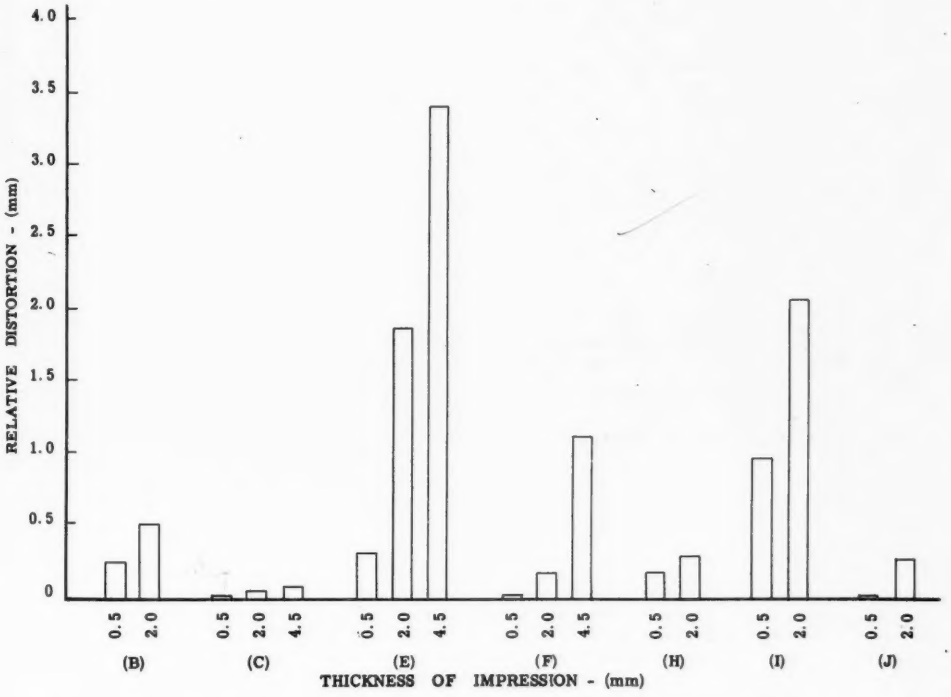

Fig. 3.—The relative distortion with varying thicknesses of impression material. In all cases, reducing the bulk increased accuracy.

Actually, a recommended curing time of 10 minutes is somewhat of a compromise between a practical curing time when the materials are setting in a patient's mouth and a curing time which would result in maximum accuracy of reproduction. Also, it should be understood that polymerization and dimensional change (shrinkage) continue for many hours after the arbitrary 10-minute cure. This is true both for the cross-linkage polymerization of the silicones and the straight-chain polymerization of the Thiokols.

Bulk of Material.—It has been demonstrated previously that a minimum bulk of material is essential for maximum reproduction with the Thiokols.[9] The same observations can be made for the silicones. The results seen in Fig. 3 clearly emphasize that accuracy is reduced as the thickness of material increases. In these

tests, care had been taken to have an even distribution of bulk around the impression. Results, on a limited series, indicated that uneven distribution increased distortion. The impression tray must be carefully selected and adjusted to provide minimum and uniform bulk of silicone.

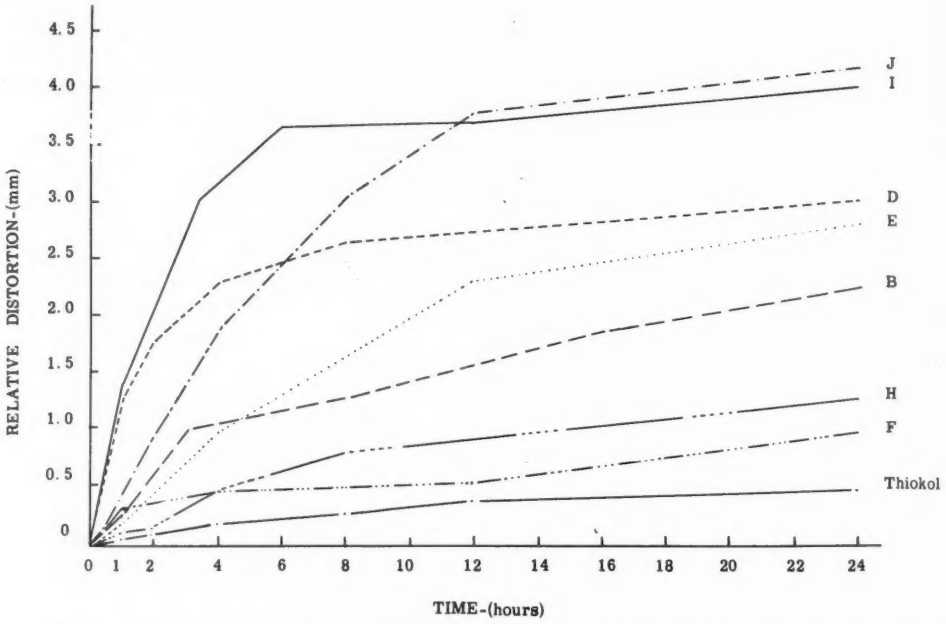

Fig. 4.—The relative distortion of impressions when stored at room temperature. The results on one typical Thiokol are also shown. The data have been corrected for any initial inaccuracy of the die when poured immediately. These dimensional changes may be related to continued curing, release of stress, collapse of internal bubbles, or volatilization of some of the ingredients.

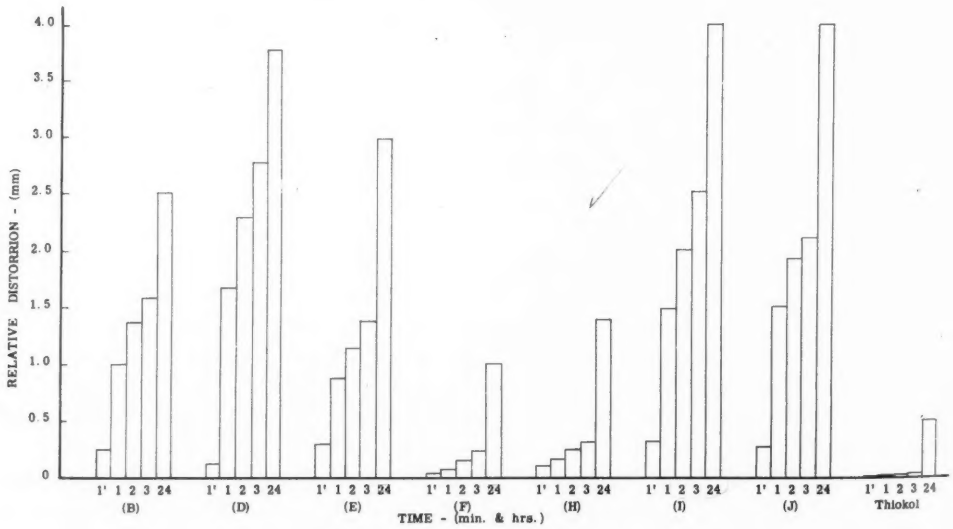

Fig. 5.—The distortion of impressions when successive dies are poured in the same impression at varying time intervals.

Dimensional Stability.—As with the other types of impression materials, the most accurate results can be attained only when the impresssion is poured immediately (Fig. 4). It is apparent that the magnitude of distortion varies considerably with the brand of material. As compared to one of the popular Thiokols, the problem of distortion on standing is greater with the available silicones.

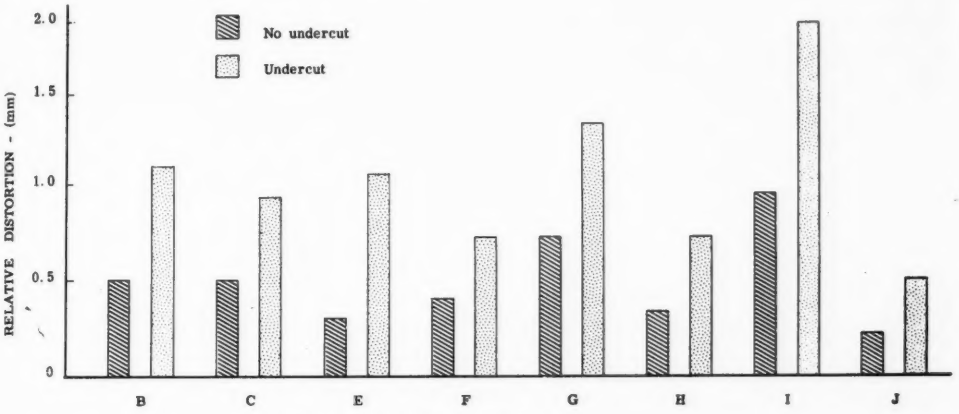

Fig. 6.—The effect of undercuts on accuracy.

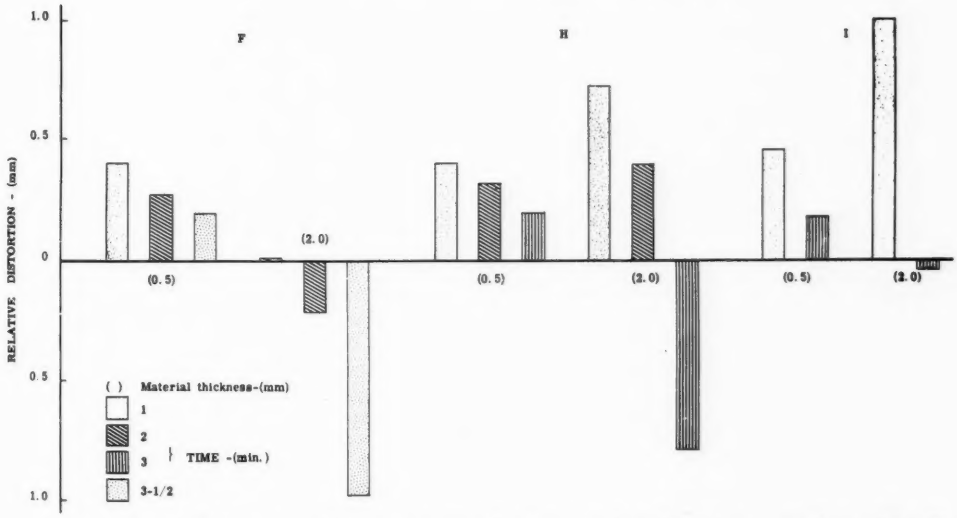

Fig. 7.—The influence of stiffness of material, showing the distortion occurring with silicones allowed to cure for varying periods of time before seating the band. Two thicknesses of material were used.

Consecutive Pours.—The distortion occurring by pouring successive dies in the same impression at various time intervals can be seen in Fig. 5. The times for pouring the dies were arbitrarily selected. However, a minimum of one hour was used between individual pours since it is desirable to allow the stone die to harden for 30 minutes to 1 hour before separation. The results indicate that, due to the lack of dimensional stability, the distortion increased with each die and is greater than with the consecutive dies made from a Thiokol impression.

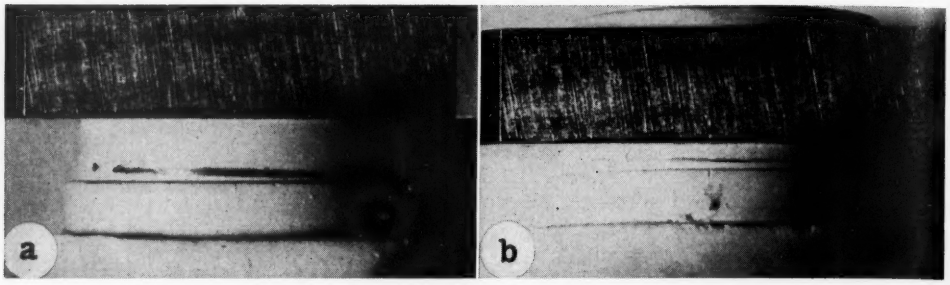

Fig. 8.—The fit of the master ring on an oversized die *a*, and an undersized die *b*, as compared to the master die (see Fig. 1, *d*). The oversized die resulted when material H had been cured only one minute before seating, while the undersized die resulted when the same silicone was cured 3 minutes before seating.

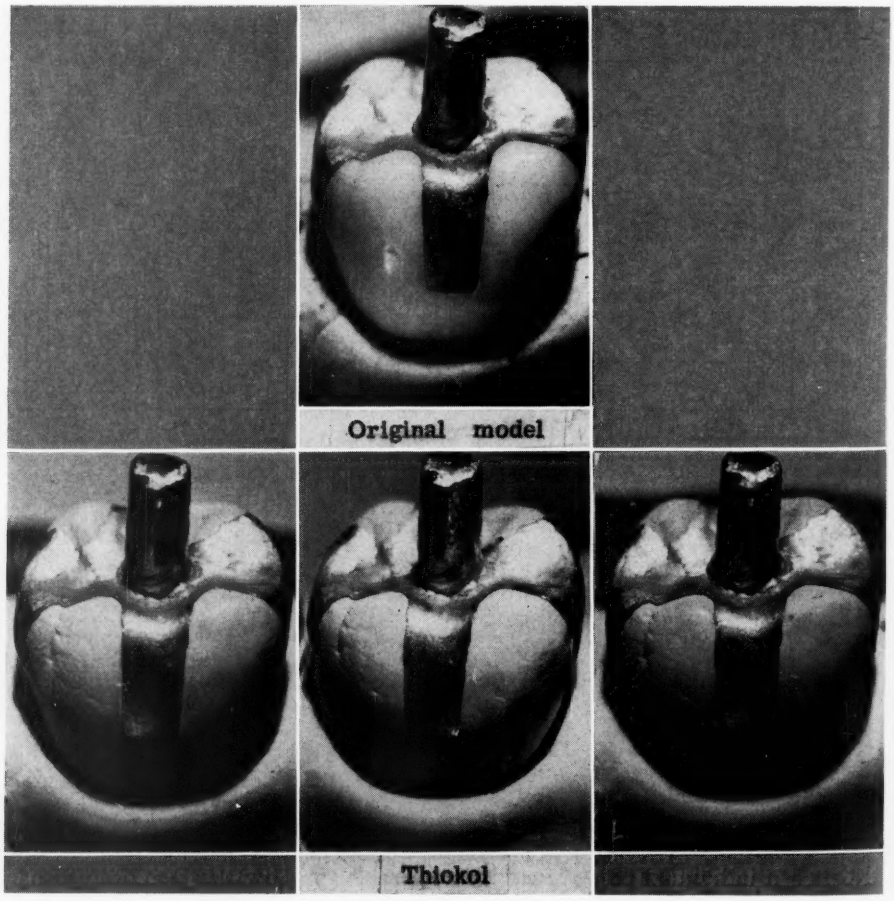

Fig. 9.—An MODBL casting seated on the original model (top). The hydrocal cast, *left*, was poured from a Thiokol impression at 10 minutes, *center*, at 6 hours, and *right*, at 24 hours.

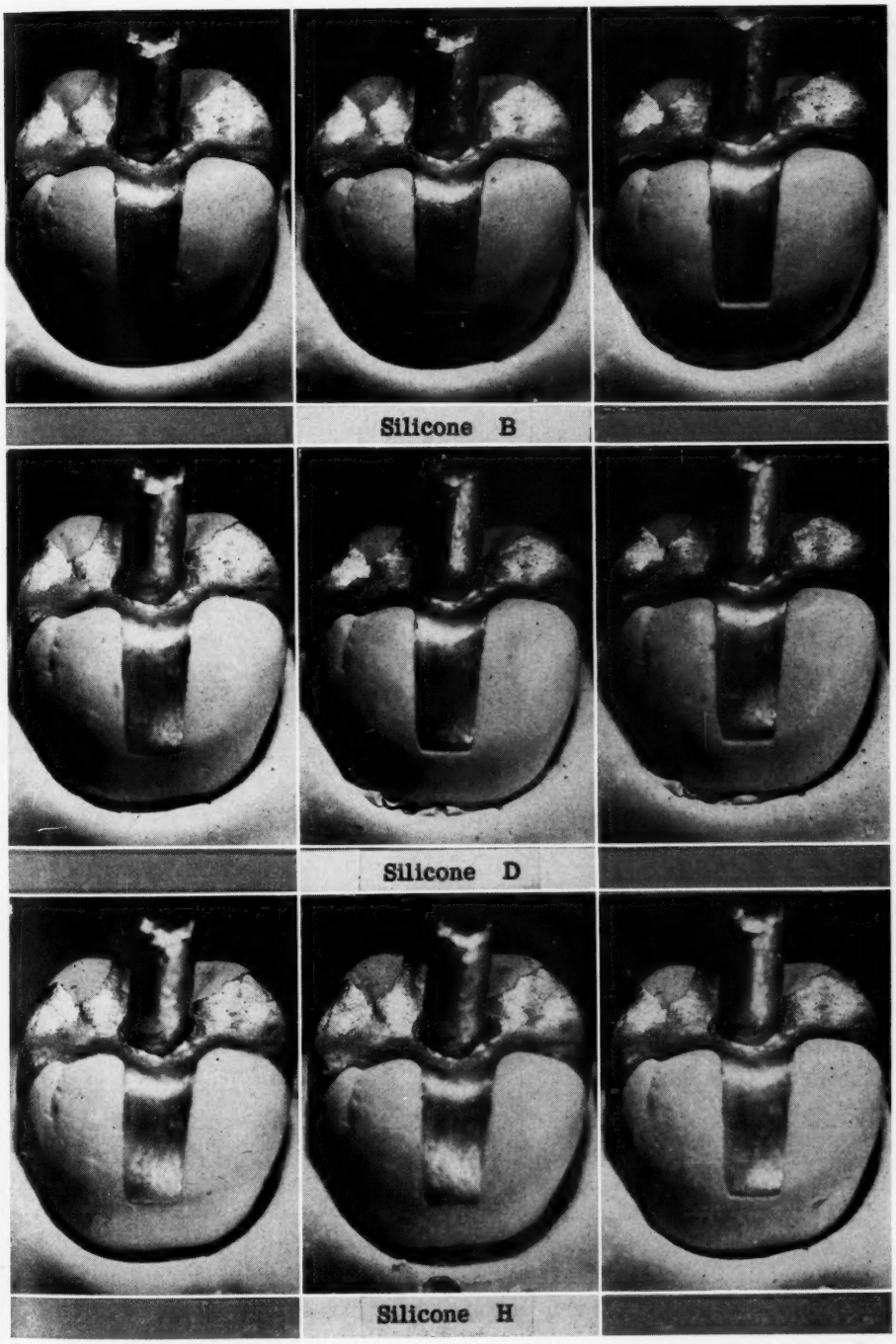

Fig. 10.—The fit of the master casting, as shown in Fig. 9, seated on stone dies poured in 3 silicone impression materials. *Left*, 10 minutes, *center*, 6 hours, and *right*, 24 hours.

Effect of Undercuts.—The addition of the undercut to the MOD die increased the distortion for each of the materials tested (Fig. 6). It is apparent that, as with hydrocolloid,[12,13] maximum accuracy will be achieved only by minimizing undercuts and making the abutments parallel. It will be noted that none of the silicones reproduced the original model perfectly even when no undercuts were present in the original model. However, the master casting used in this series fits the original model very snugly and provides a most critical test.

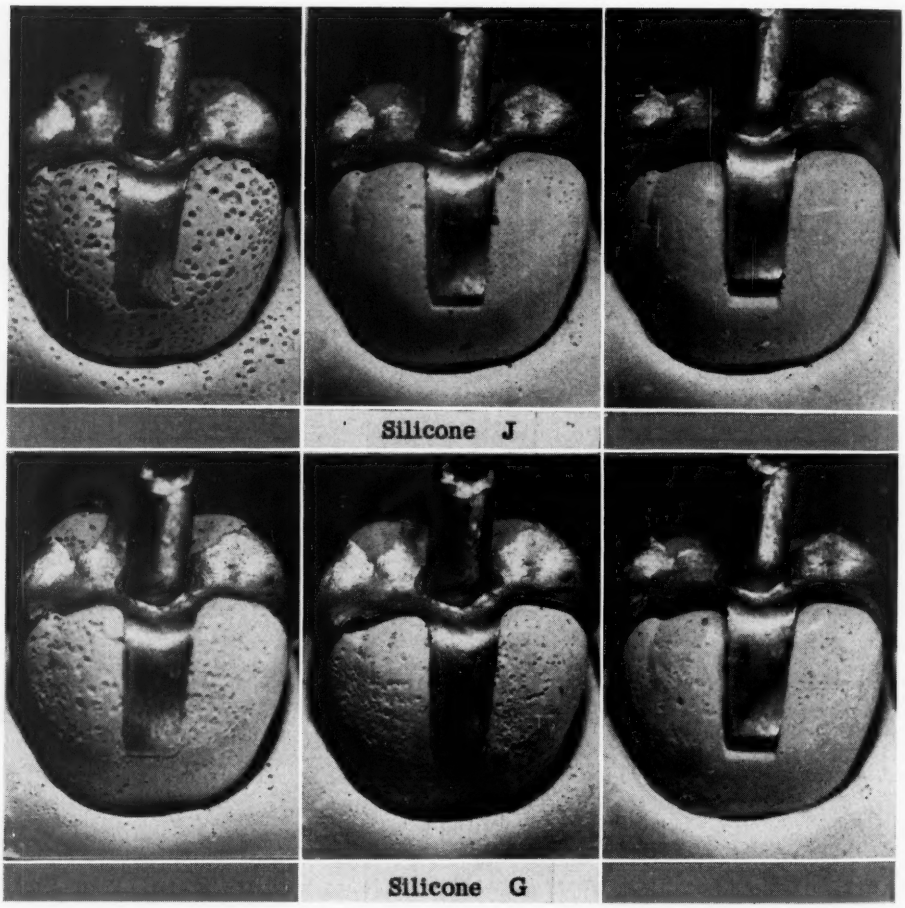

Fig. 11.—The fit of the master casting with two other silicones at the same time intervals as in Figs. 9 and 10. Note the bubble formation in the cast due to hydrogen evolution, even when poured at 24 hours.

Stiffness of Material.—The stiffness of the material at the time the impression is seated does influence accuracy. If the material has cured beyond a certain point, elastic deformation will occur upon removal of the tray and result in a smaller die than when a less stiff material is used. This can be seen in Fig. 7 where the accuracy of reproduction was measured by employing varying curing times before seating of the band. Two thicknesses of material (0.5 and 2.0 mm.) were used.

The three materials illustrated showed this effect to a greater extent than did the others. It is obvious that as the viscosity increases before seating, the resulting die invariably becomes smaller. The differences naturally increase with bulk of silicone. Typical examples can be seen in Fig. 8 where the machined ring is placed on stone dies poured in two impressions in which varying stiffnesses of silicone were used. The difference in the size of the resulting stone die is obvious. These data clearly indicate the danger in using the material after it becomes too stiff. Ideally, each material probably has an optimum time at which it should be carried to the mouth.

Sectional Impressions.—In order to reproduce more clearly the actual conditions of clinical use, sectional tray impressions were taken of four prepared Dentoform teeth, using an adjusted stock acrylic tray. The most critical preparation and casting in this series is the MODBL on the first molar. In Figs. 9, 10, and 11 the master casting can be seen seated on hydrocal dies poured at 10 minutes and 6 and 24 hours from the time the impression was removed from the model. It is apparent that none of the materials tested have sufficient dimensional stability to store the impression safely. These observations closely parallel the results obtained on the steel dies and disclose that the distortion with time is greater than for the Thiokols. The problem of hydrogen evolution and pitted surfaces on the hydrocal die still remains most real with two of the silicones (Fig. 11). The use of a heavy or rapid setting mix of stone will reduce the surface pits markedly, but will not entirely prevent them.

DISCUSSION

The silicones have handling and esthetic characteristics which are superior in many respects to the Thiokols. As a group, however, they appear to be somewhat more unstable, particularly in regard to shelf life. Certainly, the rapid alterations in formulation which many of them are undergoing is improving many of their past deficiencies. In general, the same variables which influence the accuracy of the Thiokols, namely, curing time, bulk of material, dimensional stability, and stiffness, also contribute to the clinical success of these materials. It would be unwise to use the data presented here for comparison of one material to another since, unquestionably, there will be marked batch changes occurring before this article is published. However, the general observations made here will undoubtedly remain valid.

SUMMARY

Seven popular silicone impression materials were investigated to determine various factors which influence their accuracy. The method of study involved the use of master castings tried on hydrocal dies poured in impressions treated in varying ways. MOD and full-crown steel dies and a series of dental preparations in technique teeth were employed. The following observations were made:

1. If there is a sufficiently long setting time, use of a double-mix procedure, either with or without a special viscosity syringe material, will produce more accurate impressions than a single-mix technique.

2. Although the accuracy of some of the products could be slightly improved by curing longer, 10 minutes appears to be adequate for materials presently available.

3. A uniformly thin (2.0 mm. or less) layer of silicone produces more accurate results than thicker or unevenly distributed masses of material.

4. Accuracy is improved by permitting the impression material to become very slightly elastic before seating of the band or tray; however, if it becomes too stiff, severe distortion may result.

5. With the different brands of materials, there is a wide difference in the rate and degree of distortion upon storage of the impression. As a group, the distortion is severe and storage is contraindicated.

6. Because of this continued polymerization and release of internal stress, the second or third hydrocal die poured from the same impression may be considerably less accurate than the first.

7. As with all elastic impression materials, the elasticity is limited, and any undercuts will increase distortion.

8. As a group, the present silicones show considerably more individual variations in handling characteristics and accuracy than do the Thiokols.

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CLINICAL AND PHYSICAL STUDIES OF THE SILICONE RUBBER IMPRESSION MATERIALS

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THE SILICONE IMPRESSION MATERIALS have been available in this country for over three years and are becoming increasingly popular in impression techniques in restorative dentistry. Very little information is available in the literature on the use and physical properties of these materials. Östlund[1] and McLean[2] have described the physical properties of the silicone products available in Europe. In the United States, McGregor and associates[3] of the Dow-Corning Corporation have reported on the development and application of the silicones as dental impression materials. They are elastic and comparatively stable and give clinically accurate and detailed impressions of the hard and soft tissues of the mouth. The silicone products have esthetic coloring and are easy to mix; they do not stain clothing, and normal variations in room temperature do not significantly change the setting times. In these latter properties, they show an advance on the Thiokol impression compounds.

A number of silicone polymers have been utilized, and each has exhibited some defects as an impression material: some have elastic properties inferior to the Thiokol and hydrocolloid compounds, some produce gas during polymerization and cause surface porosity on casts, and others exhibit a surface tack for a varying period of time after the impression has been made. The tackiness seems to be associated with a tendency to stick to the teeth and especially to metallic restorations. Many of the materials, which are satisfactory from the point of view of good cast surface and elastic properties, have a poor shelf life and show deterioration in their setting characteristics with storage. With the catalysts presently available, there is difficulty in achieving a sufficiently long working time for a satisfactory syringe material. In general, the silicone products have proved, so far, to be less easily electroplated than the Thiokol rubber compounds. However, rapid developments in the silicone field are bringing constant improvements, and it is believed that products free from these problems will become available.

The physical properties of particular interest to the clinician are manipulation time, setting time, consistency, elastic properties, and accuracy of the resulting casts or dies. Differing clinical procedures require different setting time and consistency values. The prosthodontist will use the materials in a different manner than the clinician in inlay, crown, or fixed partial denture work. Each needs a material to suit his individual requirements. The data presented in this report represent part of a

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study to evaluate these impression materials for use in operative dentistry in the fabrication of inlays and crowns.

The products studied are listed in Table I and are representative of the many silicone products available to the profession at the time of writing. The field of silicone chemistry is progressing rapidly and undoubtedly improvements can be

TABLE I. SILICONE RUBBER IMPRESSION PRODUCTS TESTED

PRODUCT	MANUFACTURER	DATE PURCHASED
Elasticon	Kerr Mfg. Co., Detroit	6–13–58
Syringe Elasticon	Kerr Mfg. Co., Detroit	6–13–58
SIR Tray	Acralite Co., Inc., New York	2–25–58
SIR Syringe	Acralite Co., Inc., New York	2–25–58
Silicone	Ransom & Randolph Co., Toledo	5–26–58
Siligel	Dental Perfection Co., Calif.	1–13–58
Lastic 55	Pfingst & Co., New York	5–23–57

anticipated. It is quite possible that better products will be available to the profession by the time this article is published. However, the general physical properties of setting time, consistency, and elastic properties are not likely to change to a great degree, and it is felt that the data, information, and discussions of general principles in this article will be useful and helpful to the research worker, clinician, and manufacturer. Much work remains to be done in the development of suitable tests for the evaluation of the rubber impression materials. In these studies, the general principle has been to utilize testing procedures used in previous studies by several workers in order to acquire data which could be compared with those other studies.[4-6] Opinions differ on the value and clinical interpretation of data obtained in penetrometer tests for initial and final setting times and in the exact procedures desirable in tests for elastic qualities as expressed in terms of percentage of strain and percentage of permanent deformation.

In these studies, the penetrometer tests for setting time have been used mainly to compare the setting time of one material with another under standard conditions. It is demonstrated that, so far as the products tested are concerned, there is a discrepancy between the initial setting time as determined by the penetrometer tests and the clinical behavior of the syringe products. Nevertheless, these penetrometer tests enable a rapid evaluation of the setting characteristics of a new product to be achieved, and an experienced worker can predict the clinical behavior of the material with accuracy. In this way, an economy is made in time and clinical trials. There is a growing body of opinion that percentage of permanent deformation should be measured at a constant strain value rather than at a constant load as has been done previously. In this study, both methods were used, and a comparison of the results can be seen to substantiate the general trend of opinion toward the measurement of percentage of permanent deformation at a standard degree of strain.

CLINICAL PROCEDURE IN OPERATIVE DENTISTRY

A combined syringe and tray technique has been used with the hydrocolloid products, and it has become popular with the Thiokol rubber base impression

materials. When used with suitable methods of soft tissue control, this technique seems to be the method of choice for all except simple Class I and V cavities where the use of a syringe can be discarded because of the simple cavity form and good access. These same procedures can be applied with the silicone products. It has become customary with the Thiokol products to use a fluid material in the syringe and a more viscous material in the tray. Usually, the syringe material has a longer manipulation time than the tray material, which permits the tray material to be mixed after the syringe is filled. This technique is coming into use with the silicone products. The manufacturer supplies a heavy- and a light-bodied product or one basic product with retarders and additives to enable the dentist to modify the material to suit his own purpose.

INITIAL AND FINAL SET

Initial and final setting times were determined by using the Vicat apparatus with a 3 mm. diameter needle and a load of 300 Gm. Freshly mixed impression material is placed in a metal ring 8 mm. deep and 16 mm. in diameter. The needle is allowed to contact the silicone rubber base for 10 seconds and the penetration is recorded in millimeters. This procedure is repeated at 30-second intervals. Initial set is taken as the period from the beginning of the mix to the point at which the needle no longer fully penetrates the specimen. The setting time is the time from the beginning of the mix to the first of three consecutive similar readings. At least three tests were performed on each product, and the average was taken to the nearest half minute. The tests were carried out at room temperature and humidity. The manufacturers' directions were followed in measuring the recommended proportions of the base and catalyst. The results obtained with the eight products tested are shown in Table II. It can be seen that the initial setting times vary from 2.5 to 10.5 minutes, and the final setting times from 5.0 to 15.5 minutes.

TABLE II. INITIAL AND FINAL SET AT ROOM TEMPERATURE BY VICAT NEEDLE TO NEAREST 0.5 MINUTE

PRODUCT	INITIAL SET	FINAL SET
A. Tray	8.5	12.5
B. Syringe	10.5	15.5
C. Tray	4.0	8.5
D. Syringe	3.0	6.5
E. Tray	2.5	5.5
Syringe Mix	4.0	7.0
F.	5.5	9.0
G.	3.5	5.0

In two brands, the syringe material (B, E syringe mix) has a longer working time than the tray material. In clinical use of these products, the syringe material is mixed first, and the syringe is loaded before mixing the tray material. The proportions used with product E were 4 inches of base to one drop of catalyst for the syringe mix and 4 inches of base to two drops of catalyst and one drop of heavy-bodied liquid for the tray mix.

It was noticed in clinical use of the syringe materials that the initial set as determined with the Vicat test was longer than the time during which the material could be ejected from the syringe. To determine the time during which the material could be ejected from a syringe, a syringe was loaded with material mixed according to the manufacturers' directions and ejected every 30 seconds using the normal amount of hand pressure used in the clinic. The time was noted at which the material would no longer flow from the syringe and coalesce into a creamy mass. The previous reading was taken as an indication of the period of time during which the product could be used in a syringe. The comparison between initial set determined with the Vicat test and that determined by the syringe method is shown in Table III for two products. It can be seen that in these two cases the actual time available for use in a syringe is appreciably less than that indicated by the Vicat test. This was found to be the case with most silicone rubber impression materials tested.

TABLE III. COMPARISON OF INITIAL SET OF A SYRINGE-TYPE SILICONE DETERMINED BY VICAT METHOD WITH INITIAL SET DETERMINED BY SYRINGE METHOD (ROOM TEMPERATURE 80° F. ± 2°)

PRODUCT	VICAT—INITIAL SET	SYRINGE—INITIAL SET
B	10.5	6.5
D	3.0	1.5

EFFECT OF TEMPERATURE ON INITIAL SET

The Thiokol products have been found to be sensitive to changes in room temperature.[5] High room temperatures speed the setting of these products, and, in clinical use, it may become difficult to complete the ejection of the syringe material before setting occurs. To determine the effect of variations in room temperature on a silicone product, the initial set of a syringe material was determined using the syringe method described above. The material was mixed on a glass slab which had been heated or cooled to the temperature under test and loaded into a syringe at the same temperature. During ejection at intervals of 30 seconds, the syringe was immersed in a water bath at the temperature under test. In this way the initial setting time was determined at 10° F. intervals from 50° F. to 100° F. The results are shown in comparison with a similar test on a comparable Thiokol product in the graph in Fig. 1. It can be seen that the variation in setting time over the temperature range of 70° to 90° F. is 1.5 minutes for the silicone material and 5 minutes for the comparable Thiokol product.

EFFECT OF VARIATION IN CATALYST CONCENTRATION ON INITIAL SET

McGregor[3] has described the adjustment of the setting rate to suit different clinical situations. Dilution of the catalyst with low-viscosity dimethyl polysiloxanes or long-chain alcohols is a common procedure where liquid catalysts are desired. Another method is to dilute with suitable fillers and form a paste catalyst. However, the range over which the reaction can be varied is very small. From the clini-

cal standpoint, it is difficult to get adequate working time with many of the silicones. Dilution of the catalyst to a point where adequate clinical working time is available for use in a syringe results in an incomplete polymerization of the material, a very long final setting time, and frequently a tacky surface to the impression.

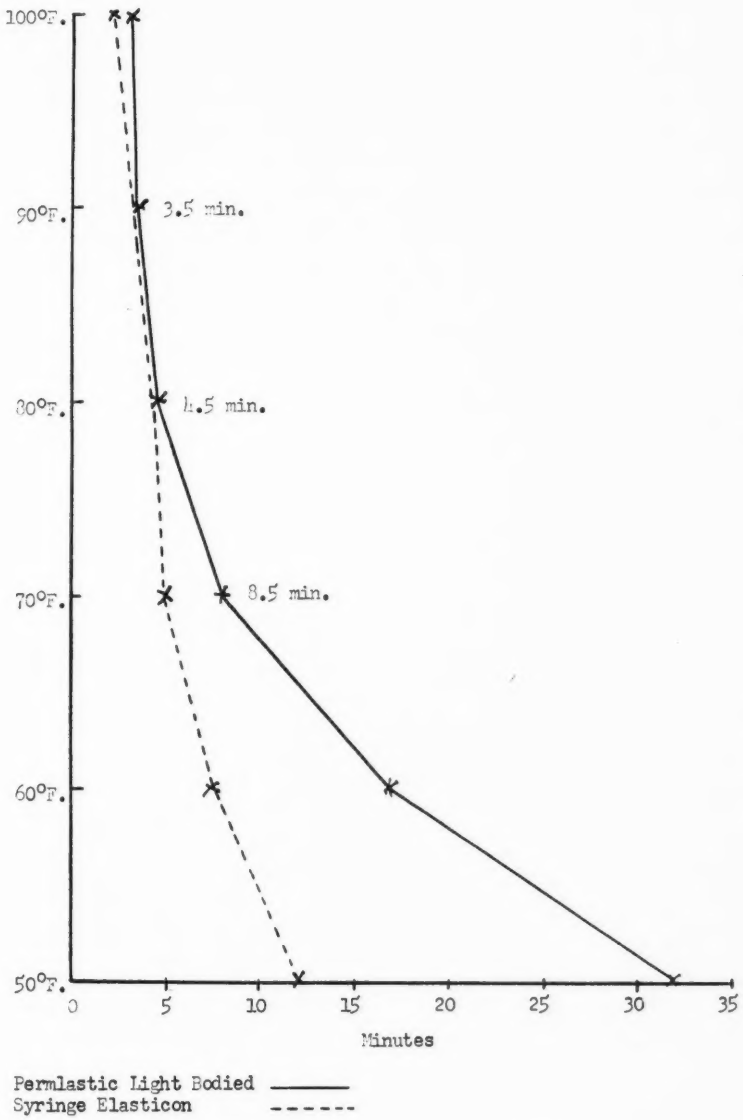

Fig. 1.—Effect of room temperature on initial set.

The effect of variations in catalyst concentration on the initial setting time of one product is seen in Fig. 2. Catalyst strengths of 100, 85, 75, and 60 per cent were used, the last three concentrations being made by dilution of the catalyst

fluid with an inert liquid supplied by the manufacturers. The initial setting time was determined by the syringe method described above. The initial setting time varied from 6.5 minutes with the 60 per cent concentration to 2 minutes with the 100 per cent concentration. The mixes made with the 60, 75, and 85 per cent concentrations failed to achieve a final set within a time convenient for clinical use.

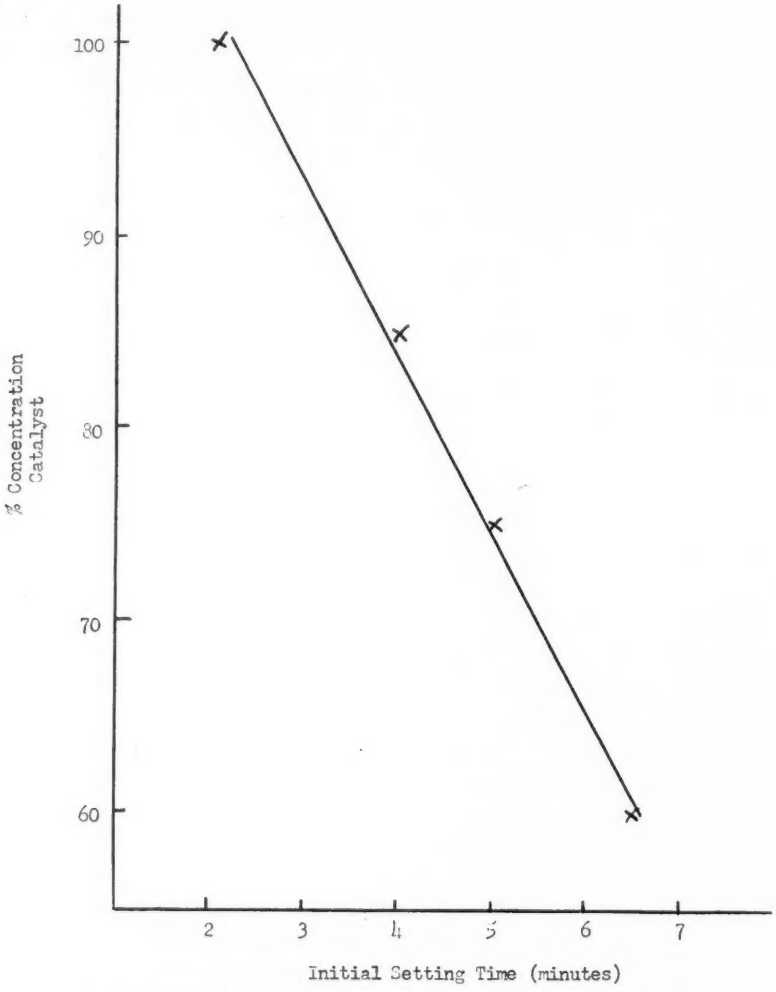

Fig. 2.—Effect of catalyst concentration on initial setting time.

This is the case with many of the available silicones, in which a reduction of the catalyst concentration or quantity to give clinically convenient working times for syringe use results in incomplete setting and the development of a tacky surface.

CONSISTENCY

To compare the consistency of the various products, a modification of the consistency test in A.D.A. Specification No. 8 for zinc phosphate cements was used. A standard quantity (0.1 c.c.) of mixed impression paste was placed between two

glass plates and 2 minutes after the beginning of mix a 500 Gm. weight was rested on the upper plate. Eight minutes later the average diameter of the resulting disk was measured.

The values obtained are listed in Table IV and range from 15 to 31 mm. This range is similar to values obtained with the Thiokol materials.[6] The syringe material B has a value of 31 mm., and clinical experience with the silicone and Thiokol materials indicates this to be suitable consistency for use in a syringe. Values in the range of from 15 to 24 mm. give a stiff-bodied impression material which works well in a tray when combined with a more fluid material in the syringe. The disk sizes obtained in this test are influenced to some extent by the setting times of the material. The syringe products D and E have shorter setting times when compared with syringe product B, and this is reflected in the considerably smaller disk sizes of 19 mm. and 23 mm. The consistencies of these materials during their working time are not as stiff as the disk size indicates.

TABLE IV. CONSISTENCY TEST*

PRODUCT	DISK SIZE (MILLIMETERS)	FINAL SET (MINUTES)
A. Tray	27	12.5
B. Syringe	31	15.5
C. Tray	17	8.5
D. Syringe	19	7.0
E. Tray	15	5.5
Syringe	23	7.0
F.	24	7.0
G.	18	5.0

*Five hundred grams are applied at 2 minutes and removed at 10 minutes; room temperature 75° ± 3° F.

PERCENTAGE OF STRAIN AND PERCENTAGE OF PERMANENT DEFORMATION

The percentage of strain is of interest in relation to the ease of withdrawal of an impression and also its ability to support the weight of unset cast stone without distortion when the impression is poured. The percentage of permanent deformation or set gives an indication of the amount of elastic recovery which takes place after the impression has been deformed, as occurs during removal from an undercut area in the mouth. The test outlined in A.D.A. Specification No. 11 for agar hydrocolloid impression materials was used to investigate these properties, but the method of preparing the specimen was modified. In addition, the percentage of permanent deformation was tested by the 12 per cent deformation method described by Cresson.[7] The specimens used in both of these tests were prepared using a metal mold 0.5 inch inside diameter, 0.75 inch outside diameter, and 0.75 inch high. The lubricated mold was overfilled with freshly mixed material, placed on a flat glass plate, and another glass plate was pressed on top to remove excess material. Two minutes from the beginning of the mix, the mold, with the glass plates still in place, was immersed in a 37° C. water bath. Seven and one-half minutes from the beginning of the mix the specimen was removed from the mold and tested at eight minutes.

The results obtained by using the A.D.A. No. 11 Specification test are shown in Table V, columns 1 and 2. It can be seen that there is a wide range of values for both percentage of strain and percentage of permanent deformation. The values

TABLE V. PERCENTAGE OF STRAIN AND PERCENTAGE OF PERMANENT DEFORMATION—PROPERTIES OF THE SILICONE IMPRESSION MATERIALS*

	1	2	3
PRODUCT	PERCENTAGE OF STRAIN	PERCENTAGE OF PERMANENT DEFORMATION	PERCENTAGE OF PERMANENT DEFORMATION AT 12 PER CENT STRAIN
A. Tray	19.6	9.1	2.8
B. Syringe	19.6	5.9	3.5
C. Tray	36.7	14.8	4.9
D. Syringe	16.1	2.5	1.7
E. Tray	8.8	0.9	0.9
Syringe	21.1	3.7	2.5
F.	6.1	0.8	1.4
G.	7.7	0.9	1.3

*Two minutes after mixing, specimen is stored in water at 37° C. for 5½ minutes and tested at 8 minutes.

for percentage of strain vary from 6.1 per cent with product F to as much as 36.7 per cent with product C, which was showing age changes and did not set completely. In clinical use, it has been found that products with strain values higher than about 20 per cent are too flexible for convenient use. The percentage of permanent deformation values in this test range from 0.8 to 14.8 per cent. It should be noted that this latter value of permanent deformation was registered at a percentage of strain of 36.7 which is considerably higher than would occur in normal use of the material. It is unlikely that such a permanent deformation could occur in clinical use. In this respect, the test of permanent deformation at a constant strain of 12 per cent gives values for percentage of deformation for each product which can be compared more satisfactorily. Values of permanent deformation so obtained are given in Table V, column 3. These values range from 0.9 to 4.9 per cent and, with the exception of product C, are all within a clinically acceptable range. Product C showed age changes and did not set completely.

The values in Table VI show the percentage of permanent deformation obtained at varying times after the beginning of the mix. Tests of percentage of permanent deformation were carried out by the method of the A.D.A. Specification No. 11 for hydrocolloids. The mold described above was used, but the specimens were stored at room temperature for periods of 10, 15, 20, 25, and 30 minutes before testing. This product (D) had a Vicat final set of 6.5 minutes. It can be seen that there is a very rapid improvement of the elastic qualities of the product during the first 20 minutes until at 25 minutes the value of percentage of permanent deformation is 0.0 per cent. This tends to substantiate the value of leaving these impression materials in place in the mouth for as long a period as is clinically possible if the most accurate results are to be obtained. Obviously, it is not possible to leave

the impression in the mouth until the maximum resistance is developed, and a compromise has to be made for clinical convenience. The percentage of strain values decrease from 15.3 to 8.0 per cent over the first 30 minutes. At the end of 30

TABLE VI. RELATION OF PERCENTAGE OF STRAIN AND PERCENTAGE OF PERMANENT DEFORMATION VALUES TO TIME AFTER MIXING

TIME (MINUTES)	PERCENTAGE OF STRAIN	PERCENTAGE OF PERMANENT DEFORMATION
10	15.33	2.44
15	10.40	0.93
20	10.66	0.06
25	8.40	0.00
30	8.00	0.00

minutes, the impression will resist deformation better when stone is poured into the impression. This applies especially to thin cervical and proximal areas of the impression.

CLINICAL EVALUATION

Several silicone products have been used in the production of gold inlays, both on typodonts and on patients. Many of the products show good promise, but each presented one or more of the problems indicated in this study of the physical properties. When carefully handled within the inherent limitation of the material, the clinical accuracy of restorations appears to be acceptable and compares favorably with that of restorations made with other elastic impression materials. However, because of the defects of the present silicones as impression materials, results were inconsistent. These defects have been indicated as being short working times or, where longer working times are available, they have been accompanied by incomplete setting and a tacky surface. With some materials, gas production has resulted in a porous surface on the stone cast, and some products have shown age changes resulting in incomplete setting. The silicone products available at this time have not proved completely acceptable for routine use in the production of gold inlay restorations. However, it is anticipated that improvements will be forthcoming and that acceptable material will become available.

CONCLUSIONS

1. The products tested had a range of initial setting times from 2.5 to 10.5 minutes when tested with a Vicat penetrometer. The final setting times ranged from 5.0 to 15.5 minutes.

2. The time available for ejection of the silicone syringe materials is appreciably less than that indicated by the initial set as determined by the Vicat test.

3. The silicone impression materials are significantly less sensitive to changes in room temperature than the Thiokol impression products. One product tested over the range 70° to 90° F. showed a 1.5-minute reduction in the initial setting

time. A comparable Thiokol product showed a 5-minute acceleration over the same range of temperature increase.

4. Variations of the concentration of the active ingredient in the catalyst over the range 60 to 100 per cent with one silicone material gave an initial setting time range of 6.5 to 2 minutes using the syringe method of testing initial set.

5. The silicone products tested showed consistency values over the range 15 to 31 mm. A typical syringe product had a value of 31 mm., which is an acceptable value. Products for use in a tray ranged from 15 to 27 mm. in consistency values.

6. The values obtained in tests of percentage of strain and percentage of permanent deformation showed all products to be satisfactory except where age changes delay the final set. These values show a considerable improvement over many of the earlier batches of these products.

7. The values of percentage of strain and percentage of permanent deformation improve rapidly during the first half hour after mixing. Accuracy will be enhanced by leaving the impression in the mouth as long as is clinically convenient before removing.

8. In clinical trials, the materials were used in syringe and tray techniques in the production of single and multiple inlays. When handled within the limitation of the materials, results were good. Results were inconsistent, however, due to one or another of the factors which have been discussed.

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SOME PHYSICAL PROPERTIES OF THREE DENTAL PORCELAINS

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THE ESTHETIC REQUIREMENTS OF modern dentistry demand the use of materials which imitate natural tooth enamel. For this purpose, the highly vitreous dental porcelains equal or, in most cases, excel other restorative materials of today.

Although the properties of porcelain require very exacting techniques to meet modern standards, leading clinicians have gradually developed ceramics into an important branch of restorative dentistry. Their methods of fabricating dental restorations which resemble living tooth structure are unique among ceramic practices.[1] Since the properties of dental porcelains influence the fabrication of porcelain restorations, knowledge of these porcelains is important to the practicing dentist for developing new techniques in dental ceramics.

PURPOSE OF THE INVESTIGATION

The purpose of this study was to obtain data for correlating physical properties with the structures of fired and unfired dental porcelains. Clark,[2] Gill,[3] and others have used principles formed from similar basic research to explain certain reactions occurring under dental technical procedures.

It has not been practical to measure all the properties of dental porcelains. For example, electrical and magnetic properties are not required in dentistry. Optical characteristics, color, and impact strength are very important to dentistry, but methods of measuring these have not yet been standardized. The properties measured in this investigation were transverse strength, firing shrinkage, specific gravity, and porosity.

LITERATURE SURVEY

Quantitative data on dental porcelains is obtained principally from scientific studies made by clinicians in dental ceramics. The word "condensing" has been used in dental research to describe the procedure which is called "compaction" or "forming" in the field of ceramics. Although the terms are synonymous, "compacting" has been adopted in this paper to avoid confusion with the references on ceramic materials. Since this manuscript was prepared originally, William C. Bell,[4] in "An Introduction to the Vibratory Compaction of Powders," has discussed the kinetic energy input required for compacting dental porcelain compositions made up entirely of nonplastic particles. Clark[2] showed that fired shrinkage above 10

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per cent was related to the amount of compaction of the porcelain powder. Gill[3] found that viscosity of the moist powder was a factor in condensation or compaction.

Skinner and Fitzgerald[5] observed little difference in apparent specific gravity values obtained under identical methods of compaction. They concluded that, in general, low-fusing dental porcelains exhibited greater shrinkage and that transverse strength measurements were independent of firing temperature.

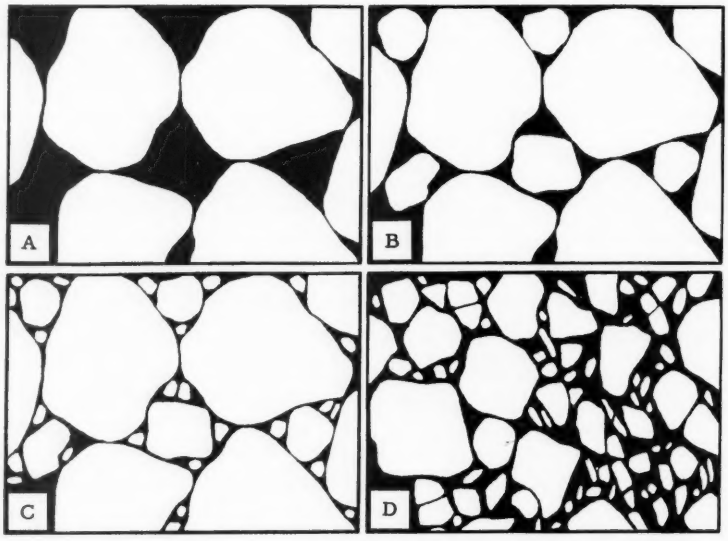

Fig. 1.—The effect of particle size on condensation. *A*, 45 per cent void space: one size. *B*, 25 per cent void space: two sizes. *C*, 22 per cent void space: three or more sizes. *D*, Dental porcelains have 30 to 40 per cent shrinkage.

Sayre[6] found the apparent specific gravity of fired porcelains to be practically independent of methods of compaction and firing. Shrinkage was less under vibratory methods, and there was a tendency for transverse strength to vary inversely with volumetric shrinkage. On the other hand, Moldal[7] noticed variation in specific gravity in different brands of opaque dental porcelains; in all cases they were found to be higher than the body porcelains. He also observed greater volume changes in opaque porcelains and considerable variation in transverse strength.

Much of the dental literature has been summarized by Skinner.[8] Sacchi and Paffenbarger[9] recently reported the compressive strength, coefficient of thermal expansion, and solubility of one high- and two low-fusing porcelains and of powdered porcelain teeth.

COMPOSITION OF PORCELAINS

A high-, medium-, and low-fusing porcelain were chosen from Dentsply, Steele's, and S. S. White body porcelains. The high-fusing powder was composed principally of feldspar, and the other two were glasses which contained feldspar minerals. The absence of clay or kaolin in the powders was verified through x-ray diffraction analysis, but some crystalline silica was detected.

The retention of shape by the porcelain after compaction depended primarily upon the amount and distribution of the different sizes of particles since no binder was added to the powders. The effect of size on compaction of nonplastic particles is discussed by Norton.[10] When crushed particles are screened to one uniform size and vibrated into a container, the volume of the void spaces between adjacent grains is almost 45 per cent of the bulk volume (Fig. 1).

Two sizes of particles, a coarse and a fine, when thoroughly mixed together, will reduce this pore volume to 25 per cent of the bulk volume. The most efficient packing results when three or more different sizes of particles are present, and even then the void space is reduced to no less than 22 per cent of the total volume.

Fig. 2.—Pouring of dental porcelain bars.

Thus, it is apparent that the minimum volume shrinkage to be expected from melting together of the porcelain particles, during firing, is approximately one-fourth of the compacted volume. Shrinkage above this amount is related to incomplete compaction, to loss of volatile materials during firing, or to changes in the structure of the porcelain. Changes in volume and structure of the dental porcelains were studied quantitatively by measuring the specific gravities of the powders and the fired porcelain bars.

PREPARATION OF PORCELAIN BARS

Twenty-four fired samples were made of each porcelain; the shape and dimensions of these were chosen specifically for testing transverse strength. A rubber mold was used to produce bars of compacted porcelain measuring 3/16 inch in

breadth and depth and 1-1/2 inches in length. The mold was placed on a dental vibrator to compact the porcelain as the supernatant water was removed with absorbent paper. Vibration was continued until a sheen appeared over the surface of the porcelain; the time of pouring was consistent at 6 minutes for each bar (Fig. 2).

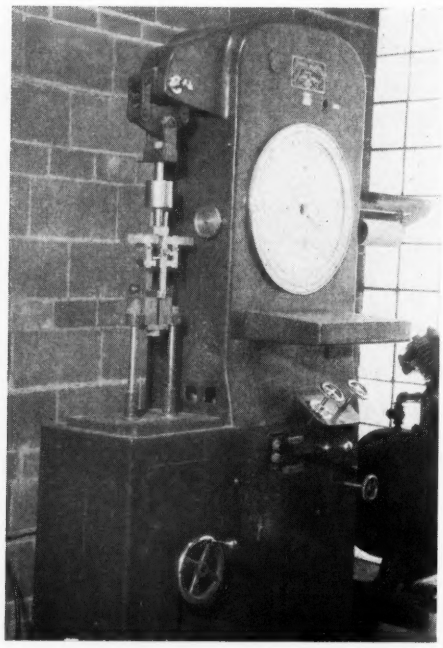

Fig. 3.—Strength testing machine.

Six bars were produced in the bisque, the glazed, and in the overfired condition for each porcelain. They were fired two at a time in the high temperature dental furnace. Fine silex was packed firmly on the tray to prevent settling of the porcelain. The tray and samples were preheated and placed into the hot furnace at 500° F. below the final temperature. The rate of firing was 50° F. per minute to the bisque (medium biscuit) or glaze temperature, and a holding time was used at the glaze temperature to produce the overfired bars. The bars and tray together were cooled to room temperature under a Pyrex dish.

The bisque-firing was carried to an eggshell texture on the porcelain surface. A high glaze was obtained in the glaze samples, and the overfired porcelains were made as vitreous as possible without complete loss of shape.

One set of fifteen bars was used to study the effect on strength of roughening or grinding the surface. An abrasive was used after the glaze-firing to remove the glaze from four sides of the bars.

METHODS OF MEASUREMENT

Linear shrinkage measurements were made with a millimeter micrometer. Volume shrinkage and apparent specific gravity were obtained by hydrostatic

weighing of the bars. All weighings were made on a Christian Becker analytical balance. The bars were then broken in a Tinius Olsen testing machine to determine transverse strength (Fig. 3).

Subsequently, part of each bar was crushed into powder to measure the true specific gravity of the porcelain, and from this the amount of porosity in the bar was calculated. Pyknometer bottles of 25 ml. capacity were used to obtain true specific gravity, and all samples were run in triplicate to attain an agreement of 0.005.

TABLE I. PHYSICAL PROPERTIES

A. PER CENT LINEAR SHRINKAGE*

	HIGH	MEDIUM	LOW
Bisque	10.7	11.5	12.7
Glaze	11.3	12.4	13.7
Overfired	12.4	14.5	14.3

B. PER CENT VOLUME SHRINKAGE*

	HIGH	MEDIUM	LOW
Bisque	29.6	31.4	37.2
Glaze	28.2	31.3	36.6
Overfired	25.1	30.9	35.3

C. APPARENT SPECIFIC GRAVITY OF FIRED BARS

	HIGH	MEDIUM	LOW
Bisque	2.31	2.32	2.33
Glaze	2.23	2.315	2.325
Overfired	2.16	2.30	2.31

D. TRUE SPECIFIC GRAVITY OF PORCELAIN

	HIGH	MEDIUM	LOW
Powder	2.63	2.43	2.36
Bisque	2.42	2.47	2.35
Glaze	2.37	2.42	2.36
Overfired	2.42	2.45	2.37

E. VOLUME OF CLOSED PORES AS PER CENT OF FIRED BAR

	HIGH	MEDIUM	LOW
Bisque	4.55	6.07	0.85
Glaze	5.91	4.34	1.48
Overfired	10.74	6.12	2.53

F. MODULUS OF RUPTURE IN POUNDS PER SQUARE INCH

	HIGH	MEDIUM	LOW
Bisque	7005	9434	8773
Glaze	8290	9164	8887
Ground	7370	8144	9065
Overfired	6943	12427	8925

*Based on dimensions of the mold.

Procedures prescribed by Andrews[11] were followed in each type of test, and formulae were obtained from him. Individual values for transverse strength that exceeded the average by plus or minus 15 per cent were rejected and new averages determined.

No measurable amount of drying shrinkage was found in any of the porcelains.

The testing machine in Fig. 3 is used by the Ceramic Engineering Department to determine the transverse strength of ceramic materials under standard conditions. According to Andrews,[11] this test requires the forming of bars of the

ceramic material in molds 1 inch in breadth and depth and 7 inches in length. The knife edges of the machine have a 1/4 inch radius and are placed 5 inches apart. The machine has a capacity of 5,000 pounds pressure.

An adapter unit was designed for testing the small dental bars on this machine. The lower piece of the adapter was approximately the size of a standard ceramic test piece, and it rested on the knife edges described above. Upon this part, knife edges of 3/32 of an inch in diameter were placed 1 inch apart to hold the dental bars. The breaking force was applied through the knife edge of a second, upper part, at the center of the porcelain bar, 1/2 inch distant from each lower support. The rate of loading was 13 pounds per minute.

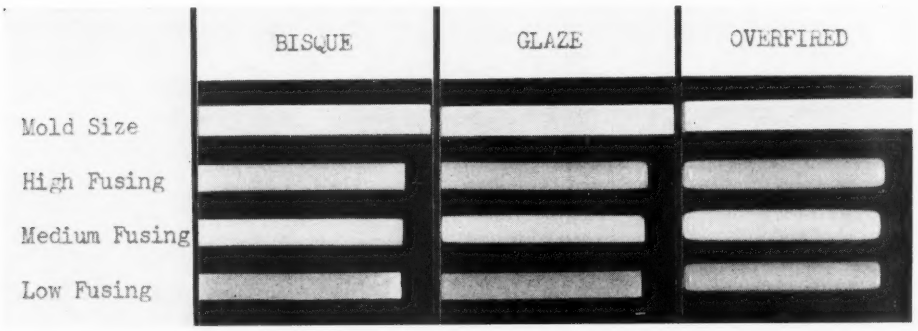

Fig. 4.—Comparison of fired porcelain bars.

FIRING SHRINKAGE OF DENTAL PORCELAINS

Linear firing shrinkage was based on the long dimension of the mold. Rounding of the ends of the bars in the overfired porcelain introduced a factor of error in measurement. The shrinkage at different temperatures is illustrated by comparing fired bars to the dimensions of the mold in which they were formed (Fig. 4).

Values obtained from the glaze-fired medium-fusing porcelain in this experiment compared favorably with those reported by Sayre[6] for Justi high-fusing porcelain. The high-fusing porcelain had the least shrinkage, and the low-fusing porcelain had the most shrinkage in the glaze-firing (Table I, *A*, and Table II).

TABLE II. COMPARISON OF PER CENT LINEAR FIRING SHRINKAGE

INVESTIGATION	DENTAL PORCELAIN					
Sayre[6]	Justi High					
	(C_{1A})	12.9				
Individual specimens, "standard firing"	(C_2)	12.6				
	(C_6)	12.4				
	(C_7)	11.4				
Hodson[1]		High		Medium		Low
	(7)	11.1	(31)	12.1	(55)	14.2
Individual glaze-fired specimens	(8)	11.9	(32)	12.4	(57)	13.0
	(10)	11.3	(33)	12.4	(58)	13.2
	(11)	11.6	(35)	12.6	(59)	14.0
	(12)	11.3	(36)	12.6	(60)	14.2

Among the three porcelains, shrinkage was least in the bisque-fired and greatest in the overfired, with the glaze-fired porcelains intermediate. Linear shrinkage increased in each porcelain as it was fired to higher temperatures, and the low-fusing porcelain had the most shrinkage at all firings.

Comparison of averages showed volume shrinkage greatest for low-fusing porcelain and least for the high-fusing. Furthermore, volume shrinkage decreased at higher temperatures; whereas the linear shrinkage increased (Table I,*B* and Table III).

TABLE III. COMPARISON OF PER CENT VOLUME FIRING SHRINKAGE

INVESTIGATION	DENTAL PORCELAIN					
Sayre[6]	Justi High					
Individual specimens, "standard firing"	(C_{1A}) 38.1					
	(C_2) 38.4					
	(C_6) 38.2					
	(C_7) 34.3					
Fitzgerald[8] (1936)	Justi High 32.2			Apco (Low) 33.3		
	S.S. White High 31.7					
Skinner and Fitzgerald[5]*	High		Medium		Low	
	(A) 32.2	(D)	32.6	(F)	39.5	
	(B) 31.7	(E)	34.6	(G)	33.3	
	(C) 32.3			(H)	37.4	
Moldal[7]	Justi Opaque (High) 34.4			Apco Opaque (Low) 33.7		
	S.S. White Opaque (High) 35.7					
Hodson[1]	High		Medium		Low	
	(7) 27.6	(31)	29.8	(55)	36.4	
	(8) 29.1	(32)	30.6	(57)	36.5	
Individual glaze-fired specimens	(10) 27.0	(33)	31.3	(58)	35.8	
	(11) 28.9	(35)	32.9	(59)	36.4	
	(12) 28.2	(36)	32.1	(60)	38.1	

*Justi High, Medium; S.S. White High, Medium, Low; Apco; and Twentieth Century High and Medium fusing porcelains were used.

This phenomenon is related to the viscosity and surface tension of feldspar glass. Melting of the feldspar minerals at higher temperatures produced glass of very high viscosity. The surface tension of this glass caused a shortening and thickening of the bars, thereby decreasing the dimension along which linear measurements were taken.

POROSITY IN DENTAL PORCELAINS

The increase in volume of the bars at higher firing temperatures was attributed to development of gas bubbles or to rearrangement of atoms in the structure of the porcelain causing it to expand. Both of these reactions were studied by measuring true and apparent specific gravities of the fired and unfired porcelains.

The apparent specific gravity of the bars decreased in all porcelains when they were overfired; this lower density corresponded to the increased volumes (Table I,*B* and *C*). The values for apparent specific gravity of the glaze-fired bars were compared with published data in Table IV.

TABLE IV. COMPARISON OF APPARENT SPECIFIC GRAVITY

INVESTIGATION	DENTAL PORCELAIN					
Sayre[6]	Justi High					
	(C_{1A}) 2.35					
Individual specimens, "standard firing"	(C_2) 2.33					
	(C_6) 2.27					
	(C_7) 2.28					
Fitzgerald[8] (1936)	Justi High 2.32			Apco (Low) 2.32		
	S.S. White High 2.33					
Skinner and Fitzgerald[5]*		High		Medium		Low
	(A)	2.32	(D)	2.30	(F)	2.29
Different brands of porcelain	(B)	2.33	(E)	2.32	(G)	2.32
	(C)	2.32			(H)	2.50
Moldal[7]	Justi Opaque (High) 2.38			Apco Opaque (Low) 2.46		
	S.S. White Opaque (High) 2.36					
Hodson[1]		High		Medium		Low
	(7)	2.21	(31)	2.31	(55)	2.34
	(8)	2.20	(32)	2.31	(57)	2.33
Individual glaze-fired specimens	(10)	2.25	(33)	2.31	(58)	2.32
	(11)	2.23	(35)	2.32	(59)	2.31
	(12)	2.24	(36)	2.32	(60)	2.32

*Justi High, Medium; S.S. White High, Medium, Low; Apco; and Twentieth Century High and Medium fusing porcelains were used.

The true specific gravities of the medium- and low-fusing porcelains underwent very little change from the unfired powder to the overfired porcelain. Since both of these were fritted porcelain, it is reasonable to assume that most of the chemical reactions were already completed in the preparation of the frit (Table I,*D*).

The high-fusing porcelain powder, however, was composed of minerals instead of glass. The decrease in true specific gravity between the unfired powder and the bisque-fired porcelain indicated that some loss occurred from decomposition of the feldspar as it melted into glass. No significant change in composition occurred beyond the bisque temperature.

The volume of closed pores in the fired bars was obtained by comparing the specific gravity of each bar with the specific gravity of the porcelain composing the bar (Table I,*E*). It is interesting to note that porosity in the low-fusing porcelain was much lower than in the others. It had the greatest shrinkage and the least porosity. The change in volume of the three porcelains is shown in Fig. 4.

PHYSICAL STRENGTH

Ceramic materials with good mechanical strength are usually crystalline in structure and opaque to light. Conversely, dental porcelains that are translucent enough to resemble human tooth enamel are predominantly glass in structure and, consequently, possess the physical properties of glass.

TABLE V. COMPARISON OF MODULUS OF RUPTURE IN POUNDS PER SQUARE INCH

INVESTIGATION	DENTAL PORCELAIN					
Sayre[6]	Justi High					
Individual specimens, "standard firing"	(C_{1A}) 6950					
	(C_2) 7150					
	(C_6) 5050					
	(C_7) 7250					
Fitzgerald[8] (1936)	Justi High 7800			Apco (Low) 7200		
	S.S. White High 7900					
Skinner and Fitzgerald[5]*	High Fusing		Medium		Low	
	(A) 7800	(D)	7100	(F)	3700	
Different brands of porcelain	(B) 7900	(E)	8300	(G)	7700	
	(C) 8200			(H)	7000	
Moldal[7]	Justi Opaque (High) 10400			Apco Opaque (Low) 8300		
Average of three or more trials	S.S. White Opaque (High) 8500					
Hodson[1]	High		Medium		Low	
	(7) 8470	(31)	9085	(55)	8512	
Individual glaze-fired specimens	(8) 7010	(32)	9395	(58)	9630	
	(10) 8800	(33)	9985	(60)	8520	
	(12) 8880	(35)	8160			
		(36)	9195			

*Justi High, Medium; S.S. White High, Medium, Low; Apco; and Twentieth Century High and Medium fusing porcelains were used.

The strength of glass is discussed by Scholes.[12] Two factors which must be considered in the testing of glass products are, first, that glass always fails in tension and, second, the surface of glass is the most important factor influencing its strength. All ordinary cracks in glass start from tensions produced by pressures, scratches, or abrasions; sources of these tensions are surface and internal imperfections such as gas bubbles. The place and distribution and the time when these tensions develop are factors which vary with testing conditions. The theoretical crushing strength of glass is infinite, but since glass always fails in tension, measurements of crushing or shear strength give only comparative values.

Under ordinary conditions, the elastic modulus of glass at the breaking point is about 10,000 pounds per square inch for specimens of approximately 1/4 square inch in cross-sectional area. Higher values are obtained from smaller fibers and

from disannealed or strengthened glass. Lower values are given by larger specimens and by glass with a ground or roughened surface.

The strength quoted above for a glass specimen corresponded approximately to published data on the transverse strength of dental porcelains. Dental restorations are subjected more to impact during mastication, but there is no standard method for measuring the impact strength of ceramic materials. In industry, the falling ball or the pendulum tests are used to observe, by comparison, the effect of impact on the strength of safety glass or on the adherence of enamel to metal. These tests are used for quality control in the manufacture of ceramic products, but the standard quantitative test is transverse strength or modulus of rupture.

STRENGTH OF DENTAL PORCELAINS

Transverse strength of the porcelain was measured at the breaking point of the bars under a force applied at the rate of 13 pounds per minute. They broke with the curved or conchoidal fracture that is typical of glass. A curved outline was located near the lower tension side of the bars; while the upper compressed surface showed a short, straight step in each bar. Modulus of rupture values for several porcelains were recorded in Table V.

Removal of surface glaze reduced strength in two of the porcelains but had no effect on the third. Further study is needed to determine whether grinding the surface of finished dental restorations would measurably affect their strength (Table I,*F*).

Strength appeared to be independent of porosity (Table I,*E*). Although the porcelain of greatest porosity had the least strength, the porcelain of greatest density was not as strong as the intermediate porcelain. This is shown in the following comparison of glaze-fired porcelains:

High-fusing porcelain with 8,290 psi had 5.9 per cent porosity.
Medium-fusing porcelain with 9,164 psi had 4.3 per cent porosity.
Low-fusing porcelain with 8,887 psi had 1.5 per cent porosity.

Consideration of the many factors involved in testing glass indicated that a variation of 1,000 pounds per square inch did not necessarily denote a material that was either inferior or superior to other porcelains. Generally, it was found that the vitreous porcelains were similar in strength as well as in structure.

DISCUSSION

This research together with information from the bibliography has revealed some physical properties of fired dental porcelains which can be directly related to their glass content.

The simulation of natural tooth enamel requires the translucency of vitreous porcelain, although the large amount of glass in these dental porcelains suggests that they might be characterized by lower resistance to the impact forces of mastication. More crystalline ceramic materials, that are suitable in other respects, are opaque and do not have the esthetic qualities needed in dentistry.

This explains the difficulty encountered by ceramists in finding a porcelain which has strength as well as translucency. Investigations are underway in the ceramic industry to find materials which will combine the desirable physical properties of metals with ceramics. The use of rare earth elements and the mixing of ceramic and metal powders (cermets) have been tried in the search for completely new ceramic materials. If some of the new materials should also be translucent, an ideal dental porcelain may yet be found.

Meanwhile, it remains for individual dentists to select the porcelains best suited to their own requirements and techniques. Through carefully developed empirical methods, dental clinicians have, in fact, met more exacting specifications with porcelain than might be considered practical with this material. Consequently, vitreous porcelain still remains the restorative material which best combines permanence and esthetics in replacing lost tooth structure.

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TEMPOROMANDIBULAR JOINT DISTURBANCES AS RELATED TO AN INCREASING ANGLE OF THE JAW

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CONTROVERSY HAS EXISTED in reference to the claim by some authorities that the angle of the mandible may increase considerably under certain conditions. This article is concerned only with the part that stress may play in some temporomandibular joint disturbances.

METHODS OF ANGULATION DETERMINATION

It is comparatively easy to angulate the mandible on a roentgen-ray head plate and to make other head plates from time to time for comparison. It is necessary, however, that a standardized technique for measuring the angle is used.

For this report, measurements were made from the distal part of the condyle downward to a point at the lower border of the angle, where the curvature of the ascending ramus merges with the line of the lower border of the body of the mandible (Fig. 1).

Examination of the mandibles of a large number of full-term fetuses showed that most had an angle of 140 degrees. Approximately 100 edentulous elderly people had mandibles with angles from 138 to 143 degrees as disclosed by angulating roentgen-ray head plates.

An examination of 90 disarticulated mandibles disclosed an interesting bit of information. The age, of course, was not known. Forty-one of the ninety mandibles had a complement of molars. The conditions in the corresponding maxillae were unknown. The average angle of these forty-one mandibles was 122 degrees. Twenty-five of the ninety mandibles were either edentulous or had only six anterior teeth remaining. These twenty-five mandibles had an average angle of 133 degrees. An examination of the roentgen-ray head plates of the elderly edentulous patients showed not only an angle at or above 133 degrees but also a mandible where the posterior alveolar ridge had been pulled up toward the upper alveolar ridge (Figs. 2, 3, 4).

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CAUSES OF AN INCREASED ANGLE

The power muscles concerned in occluding the teeth are the temporal, the internal pterygoid, and the masseter muscles, all of which put traction on the ascending ramus. In the ordinary daily routine of mastication, there is a comparatively light stress applied by the muscles to the mandible, and this stress is intermittent. Normally, breakfast calls for only light muscular action, lunch may call for slightly more. Dinner, however, may call for a short-term application of force up to 40 pounds or more. Therefore, the total force used in daily mastication is intermittent, and for all except short periods it is quite light.

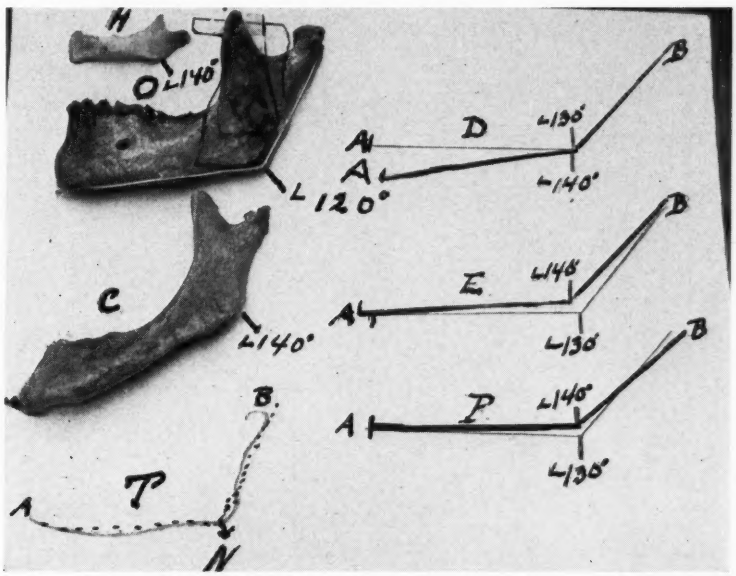

Fig. 1.—*H*, A mandible of a full-term fetus has an angle of 140 degrees. *O*, An adult mandible. Only the second and third molars are missing. The angle measures 120 degrees. The two heads of the masseter muscle are patterned in clear plastic and outlined with black borders. *C*, A mandible of an old individual. The angle measures 140 degrees. *T*, A dotted line drawing is used as a measuring line to determine the angle of the mandible. *N*, The starting point for measuring the angle. *A*, The chin. *B*, The condyle. *D*, *E*, and *F* are three possible results of a change of the angle. Many combinations of these three are possible.

The temporomandibular joint is a pressure-bearing joint, and since the mandible functions as a lever, its crushing efficiency will vary with the position of the food in relation to the fulcrum of the joint. A force of 30 pounds of pressure applied by the muscles will cause a force of 15 pounds to be developed at the molars, but only 10 pounds at the incisors. This ratio will be maintained as the force is increased.

The factor that may be very important is that of physical stress induced by nervous tension. When tensions induce bruxism or tight clenching of the teeth (most evident at night and sometimes lasting for hours), a pressure that is three times the maximum pressure used for the short periods at meal time may be de-

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 2.—The distance from the condyle to the lower incisors is 4.5 inches; the angle is 125 degrees. The subject is a 48-year-old dentulous man. The angle has increased a small amount, but there are no symptoms of temporomandibular joint disturbance.

Fig. 3.—The distance from the condyle to the lower incisors is 4.5 inches; the angle is 140 degrees. The subject is a 25-year-old dentulous man. The angle has probably changed considerably. There are no mandibular molars or second bicuspids. The upper molars have not extruded, but the lower residual ridge is drawn up almost into contact with the upper molars. Temporomandibular joint disturbances are present.

Fig. 4.—The distance from the condyle to the lower incisors is 5 inches; the angle is 142 degrees. The subject is female, has worn complete dentures for 35 years, and is 85 years of age. There are no temporomandibular joint symptoms.

veloped. Also, the dietary and masticating habits of the individual should be considered in reference to occlusal overloads.

The average mandible measures three and one-half inches from the angle to the symphysis and two and one-half inches from the angle to the most superior part of the condyle. If the chin is designated as *A* and the condyle as *B*, should the angle of the jaw change 5 degrees, the distance between *A* and *B* will be increased by ⅛ inch (Fig. 1). In edentulous mandibles, this will usually mean a slow protrusion of the chin. However, if natural anterior teeth are present, a pressure is exerted at *B* as well as at *A*. The ratio depends upon the ability of the anterior teeth to absorb the thrust because of the changing angle.

The time necessary for angle change varies widely since so many factors are involved. Once the angle starts to change, it is a continuous process as long as the causes operate. The changes cease, however, in old age when the power muscles tend to atrophy and the jaws become edentulous.

If the backward thrust of the condyle continues, a traumatizing action above and back of the condyle with a possible displacement of the meniscus exists. This condition may be interpreted as a temporomandibular joint disturbance.

When the angle of the jaw changes, a problem is posed for the periodontist, orthodontist, prosthodontist, and those dentists interested in occlusal equilibration. Unilateral loss of the posterior teeth will complicate this problem.

This is a progress report since only ninety mandibles and about one hundred roentgen-ray head plates form the basis for the findings.

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SURGICAL PREPARATION

SURGICAL CORRECTION OF MANDIBULAR PROGNATHISM IN PREPARATION FOR DENTURES

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THIS ARTICLE PRESENTS SOME of the prosthetic aspects of a new surgical technique for the repositioning of the prognathic mandible.[1] This technique involves the open vertical osteotomy of the ascending rami of the mandible.

Since the first patient was treated in August, 1954, 43 patients with prognathic mandibles have been surgically rehabilitated. Of these 43 patients 15, or about 35 per cent, required the services of a prosthodontist to complete the treatment. The prosthetic appliances made postoperatively were: 7 complete dentures, 6 removable partial dentures, and 2 complete maxillary dentures and mandibular removable partial dentures. Of the 15 patients requiring prosthodontic treatment, 8 were women and 7 were men. The ages varied from 24 to 60 years with an average age of 35. Age is no deterrent to surgical correction. Elderly patients stand elective surgery just as well as the younger patients.

The original diagnosis for complete maxillary and mandibular dentures was changed after surgery for 3 patients (20 per cent). The improved ridge relationship after surgery permitted normal stress on the remaining teeth and made removable partial dentures a better plan. All of the 15 patients had been studied previously by prosthodontists, and they had been told of the many difficulties to be encountered with complete dentures when the mandible is in a prognathic relationship.

SURGICAL PROCEDURE

Incisions approximately 3 cm. in length are made below both angles of the jaw. The periosteum is elevated from the lateral surface of the ramus so that a saw cut (Fig. 1) can be made from the deepest portion of the mandibular notch to a point approximately 1 or 2 cm. above the angle of the mandible on the posterior border. The mandible is then repositioned into a normal ridge relationship (Fig. 2)

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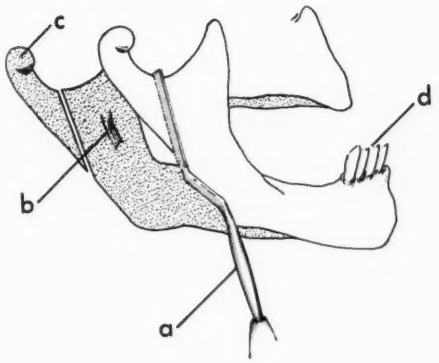

Fig. 1.

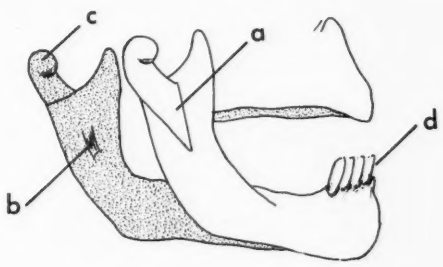

Fig. 2.

Fig. 1.—Drawing of a prognathic mandible. *a*, The saw is in position for the osteotomy of ramus, *b*, the mandibular foramen, *c*, the condyle, *d*, the protrusion of the lower teeth.

Fig. 2.—Drawing of a prognathic mandible after surgery. *a*, The condylar fragment is lateral to the ramus, *b*, the mandibular foramen, *c*, the condyle, *d*, the prognathism is corrected.

Fig. 3.

Fig. 4.

Fig. 3.—A preoperative photograph of the patient.

Fig. 4.—A postoperative photograph of the patient made approximately 7 weeks after surgery at the time the maxillomandibular fixation is removed.

with no regard to the teeth present and is immobilized by maxillomandibular wires, either by skeletal or tooth fixation. Figs. 3 to 8 show a patient treated by means of an open vertical osteotomy and the surgical prosthesis involved.

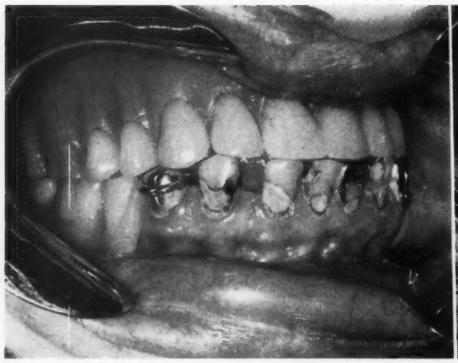

Fig. 5.

Fig. 6.

Fig. 5.—The occlusion before surgery.

Fig. 6.—The occlusion following surgery. The right mandibular cuspid was extracted at the time the arch bars were placed, and the left mandibular cuspid required pulpal drainage. The mandible has been moved more than 1 cm. posteriorly.

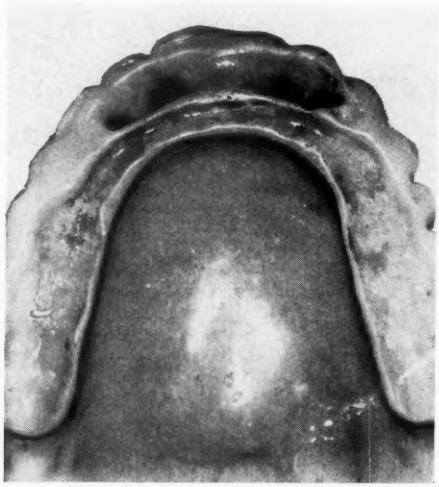

Fig. 7.—Quick cure acrylic resin is added to the old maxillary denture to establish a definite postoperative centric occlusion which will permit the fixation of the mandible in the new position. Fixation is accomplished by means of 2 wires placed just lateral to the external nares. These wires are brought down through holes in the maxillary denture and attached to an arch bar which is attached to the mandibular teeth. Eventually, the badly broken down mandibular teeth were removed, and new dentures were constructed.

SUMMARY

Many of the past difficulties associated with the surgical correction of the prognathic mandible can be avoided. The flattened appearance of the chin, the derangement in the structures in the floor of the mouth, and the possibility of delayed

union or nonunion of the parts caused by the technique of ostectomy in the body of the mandible are avoided. Also, with the technique of horizontal osteotomy of the rami there is the possibility of an increased anterior vertical dimension. The possibility of hemorrhage and the tragic sequelae of the proximal fragment being displaced medially can be avoided by using the open approach to the vertical subcondylotomy.

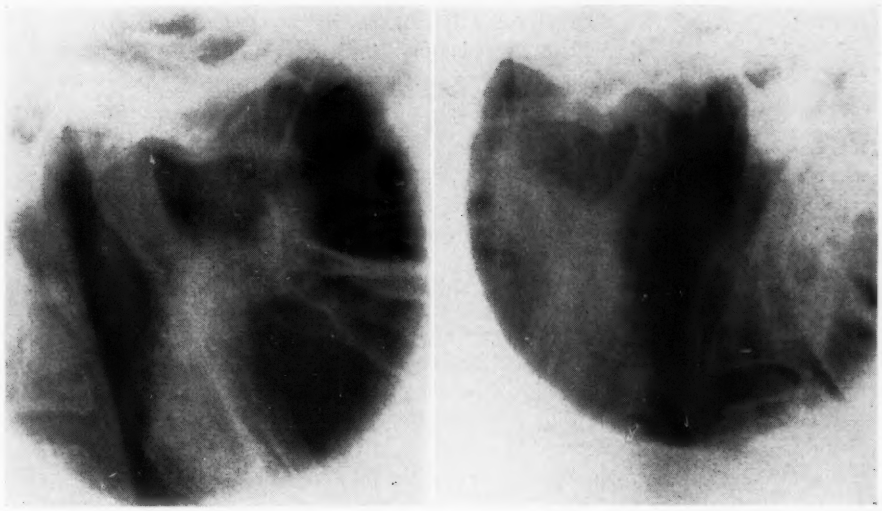

Fig. 8.—Postoperative roentgenograms made approximately 6 months after surgery show normal healing of the osteotomes. The patient had no complaints referable to the surgery or the dentures.

The postoperative jaw position in these future denture patients should be determined by the prosthodontist. He can mount the casts arbitrarily in a postoperative position, regardless of the remaining teeth, taking into consideration the ridge relationship for the dentures to be made sometime in the future.

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BOOK REVIEWS

EMERGENCY WAR SURGERY. NATO Handbook. By Brig. Gen. Sam F. Seeley, MC, USA, and the NATO Committee, Washington, D. C., published under authority of The Secretary of Defense by the United States Government Printing Office. Pp. 411, illustrated, indexed. Price $2.25.

This excellently prepared volume, representing the broad experience and practical knowledge of surgical consultants of France, the United Kingdom, and the United States, is intended to stimulate awareness of the fundamental principles of surgical care of injuries incurred in combat in order that the best possible medical service may be rendered to all members of the Allied fighting forces.

The book, containing thirty chapters, is arranged in four parts: "Types of Wounds and Injuries," "Response of the Body to Wounding," "General Considerations of Wound Management," and "Regional Wounds and Injuries." It emphasizes the importance of organized teamwork by trained personnel, their ability to adapt themselves to movement of station when required, and the fact that the standards of treatment may be followed, even in an atmosphere of confusion and disorder, if there has been intelligent planning and training. It limits its presentation to the emergency care of casualties through the first three echelons of handling and evacuation: the battalion aid station, the clearing station, and the field or evacuation hospital.

The authors' discussion of "Mass Casualties" is most informative, including the subject of thermonuclear injuries. Chapters on "Thermal Burns," "Crush Injury," "Blast Injury," "Chemical Injury," "Radiation Injuries," "Shock and Resuscitation," "Infection," "Shorting of Casualties," "Care at Battalion Aid Station," "Anesthesia and Analgesia," "Amputations," and those on regional wounds and injuries: "Soft Tissues," "Vascular System," "Bones and Joints," "Craniocerebral Areas," "Spinal Cord," "Maxillofacial," "Eye," "Ear," "Neck," "Chest," "Abdomen," "Genito-Urinary Tract," and the "Hand" are written in clear, simple, and definite language.

This handbook is not only an invaluable guide for the handling of battle casualties, but has equally great application for use by the agencies of Civil Defense in the event of catastrophy following attack involving the employment of nuclear bombs. It should be read and studied not only by members of the medical profession, but by those of the others engaged in the practice of allied phases of the healing arts. Due to its concise expression and lucid style, it may be read with understanding by laymen. It is recommended highly as a reference manual for the very important field it covers.

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THE ANATOMY OF THE HEAD AND NECK. By Barry J. Anson, Ph.D., Philadelphia, 1956, The W. B. Saunders Company. Pp. 101, illustrated, indexed. Price $6.50.

This book represents sections I and II of the book, *An Atlas of Human Anatomy*, by the same author, a work resulting from years of laboratory teaching. The drawings were made from new dissections, which are serially prepared, and presents, to some extent, the occurrence of variations. It was the intention of the author to provide an atlas which can be used by the dental practitioner as a substitute for an actual specimen.

The book is published in a cloth cover, spiral binding. A high quality smooth paper is employed. The drawings are predominantly black and white with several in color and are well

labeled. The author uses the Latin terminology in labeling the illustrations and liberal use of explanatory remarks are found throughout the book.

The Anatomy of the Head and Neck offers a well-illustrated and accurate atlas to the dental practitioner at a moderate cost. The only criticism to be offered is that some confusion might arise from the use of the Latin terminology. The book has been found to be very useful in projecting the illustrations on the screen for lecture purposes.

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ORAL SURGERY, ed. 3. By Kurt H. Thoma, D.M.D., Dr. med. dent. h. c. (Zürich), F.D.S., R.C.S. (Eng.), Hon. F.D.S., R.C.S. (Edin.), F.A.C.D., St. Louis, 1958, The C. V. Mosby Company. Pp. 1607, illustrated, indexed. Price $27.50.

Both the first edition, published in 1948, as well as the second edition, published in 1952, were comprised of two volumes in contrast to the third edition which is published as a single volume. The frequency of new editions attests to the rapidly expanding horizons in the field of oral surgery as well as in the ancillary fields of pharmacology, anesthesiology, bacteriology, physiology, pathology, and roentgenology. The author has included the new information in the third edition.

The subject matter, presented in twenty-three chapters, includes discussions about the principles of surgery, the general care of the patient, roentgenographic examination of the face and jaws, pharmacology, anesthesiology, exodontia with and without alveoloplasty, periodontal and periapical surgery, the treatment of abnormalities of the edentulous mouth (including subperiosteal denture implants), the removal of impacted and unerupted teeth, surgical eruption, positioning, transplantation and replantation of teeth, the treatment of traumatic diseases of the jaws, the treatment of the diseases of the mandibular joint, the treatment of odontogenetic diseases of the maxillary sinus, the treatment of osteomyelitis, osteitis and necrosis of the jaws, the treatment of dentoalveolar abscesses and infections of the face and neck, the treatment of diseases of the salivary and mucous glands, the treatment of diseases of the fifth and seventh cranial nerves, the treatment of cysts of the jaws, the treatment of benign tumors of the mouth and jaws, the treatment of malignant tumors found in the region of the jaws, the treatment of developmental deformities of the jaws, the treatment of acquired bone defects, and the treatment of oral abnormalities and defects.

In general, the author uses simple declarative sentences throughout the book. This makes his thoughts readily understood. Each subject is approached in a logical manner. Diagnostic problems and definitive treatments are often illustrated by detailed case reports. Line drawings, photographs, and reproductions of roentgenograms aid in the lucid presentation of the subject matter.

It seems to me that the Third Edition is a valuable contribution to the literature of oral surgery as an encyclopedia. The dentist limiting his practice to oral surgery and the young dental graduate entering oral surgical training will find this volume an excellent reference on the diagnosis and surgical treatment of the common, as well as, the rare conditions affecting the jaws and contiguous structures. The dentist in general practice will find much of interest to him. It should be helpful to him in determining whether he should carry out the indicated definitive therapy or whether he should refer the patient to a dentist in limited practice for this service.

Harry D. Spangenberg, Jr., D.D.S., M.S. in Dent. Surg.

SEVENTH ANNUAL ESSAY CONTEST

SPONSORED BY

THE AMERICAN DENTURE SOCIETY

Prizes will be awarded to the two senior dental students who submit the best essays on some phase of prosthetic dentistry in the seventh annual essay contest sponsored by The American Denture Society. The purpose of the contest is to stimulate technical writing by dental students.

The first prize is Five Hundred Dollars ($500.00) and the second prize is Three Hundred Dollars ($300.00).

RULES

1. The contest is open to all senior dental students of the United States and Canada.
2. Only two essays may be submitted from any one dental college. (It is recommended that each dental college conduct its own contest to determine the two best essays submitted by members of its senior class.)
3. Essays are to be on some phase of prosthetic dentistry and limited to a maximum of 3,000 words. The following topics are suggested:
   (a) Centric Relation and the Interocclusal Distance,
   (b) Registration of Mandibular Movements in the Construction of Complete Dentures,
   (c) Esthetics,
   (d) Diagnosis and Treatment for a Patient Requiring Unusual Prosthetic Services.
4. Essays must be worthy of publication in the JOURNAL OF PROSTHETIC DENTISTRY and must be prepared in a form which is satisfactory to the requirements of that JOURNAL.
5. The original essay and one copy must be submitted for the use of the judges.
6. Essays must be typewritten, double spaced, on a good grade of white bond paper 8½ by 11 inches. Paragraphs must be indicated clearly by indentations, and generous margins must be allowed on each page.
7. Illustrations must conform to the standards of the JOURNAL OF PROSTHETIC DENTISTY, if they are used. Only good glossy black and white photographic prints, or drawings in India ink may be used. Each illustration should be mounted on a separate sheet of paper with the figure number and the legend typed on the paper beneath the illustration.
8. The form and punctuation of references must conform to the style used in the JOURNAL OF PROSTHETIC DENTISTRY. The references must be keyed to the text material.
9. The permanent address of the author must be at the end of the reference page.
10. The student has a free range in the choice of topics within the broad interpretation of prosthetic dentistry.
11. Essays will be judged on the basis of subject matter, neatness, composition, spelling, illustrations, charts and tables, number and accuracy of references, continuity of thought, and length of the essay.
12. The judges of the contest are members of a committee of The American Denture Society. The decision of the judges is final.
13. Essays are to become the property of The American Denture Society. None will be returned.
14. All essays submitted to the contest shall be clearly marked "Contest Essay" and shall be accompanied by a letter from the professor of prosthetic dentistry and/or the dean of the dental college from which they originate. This provision is to assure the authenticity of all essays entered in the contest.
15. Essays must be postmarked on or before July 15, 1959 and sent to:

    Dr. Victor L. Steffel
    Secretary, The American Denture Society
    College of Dentistry, The Ohio State University
    Columbus 10, Ohio

NEWS AND NOTES

MEETINGS

Academy of Denture Prosthetics, Sheraton-Seelback Hotel, Louisville, Ky., April 12 to 17, 1959.

American Association for Cleft Palate Rehabilitation, Hotel Sheraton, Philadelphia, Pa., April 30 to May 2, 1959.

Congress of Dental Science, Knokke-sur-Mer, May 6 to 10, 1959. For further information, write to Albert GG Vermeersch, L.S.D., 8, Place Foch, Louvain, Belgique.

American Dental Society of Europe, Stockholm, Sweden, July 7 to 10, 1959.

Pacific Coast Society of Prosthodontists, Rickys' Hotel, Palo Alto, Calif., Aug. 13 to 15, 1959.

American Denture Society, Roosevelt Hotel, New York, N. Y., Sept. 11 to 12, 1959.

XVIth Congrès Français de Stomatologie, Paris, France, Oct. 5 to 10, 1959. For further information, write to the Secretary General, Dr. R. Bataille, 43 Rue de la Chaussée d'Antin, Paris 9, France.

ANNOUNCEMENTS

Reprints of the "Glossary of Prosthodontic Terms" may be obtained by writing to Glossary Reprints, 400 Starks Bldg., Louisville, Ky. The price is fifty cents per copy. Please make your check or money order payable to Glossary Reprints and enclose with your order.

The next examination to be given by the American Board of Prosthodontics will be held at Northwestern University, School of Dentistry, Chicago, Ill., Aug. 31 through Sept. 5, 1959.

Applications may be secured from the Secretary: Dr. Charles H. Jamieson, 563 David Whitney Bldg., Detroit 26, Mich.

Western Reserve University, School of Dentistry, announces the following postgraduate course:

Psychodynamics and Practice Administration, March 30 through April 1, 1959.

For further information and application, write to Director of Postgraduate Education, School of Dentistry, Western Reserve University, Cleveland 6, Ohio.

The Department of Stomatology, Division of Graduate Studies, School of Medicine, Boston University, announces the following postgraduate courses:

Full Denture Prosthesis, April 6 to 15, 1959.

Occlusal Adjustment, April 27 to May 1, 1959.

Endodontics, May 11 to 15, 1959.

Periodontal Prosthesis, May 18 to 22, 1959.

Surgical Techniques Employed in Periodontal Therapy, May 25 to 29, 1959.

Pulp Protection in Operative Dentistry, June 4 to 6, 1959.

Periodontal Pathology, June 8 to 12, 1959.

For further information, write to Director of Postgraduate Studies, Department of Stomatology, Massachusetts Memorial Hospital, 750 Harrison Ave., Boston 18, Mass.

Northwestern University Dental School announces the following postgraduate courses:

Prosthetic and Orthodontic Rehabilitation for the Cleft Palate Patient, April 6 and 7, 1959.

High Speed Instrumentation, April 15 and 16, 1959.

Pedodontics, April 15 and 16, 1959.

Use of Drugs in Dental Practice, April 29 to May 1, 1959.

Diagnosis, Roentgenography, and Treatment Planning, May 4 and 5, 1959.

Pedodontic Teachers' Conference, June 8 and 9, 1959.

For further information and application, write to Director of Dental Postgraduate Study, Northwestern University Dental School, 311 E. Chicago Ave., Chicago 11, Ill.

University of Pennsylvania, School of Dentistry, announces the following postgraduate courses:

Minor Tooth Movement and Temporary Stabilization, April 8 to 10, 1959.
Tenth Mid-Atlantic States Conference in Dentistry, April 12 to 17, 1959.
Endodontics, April 13 to 24, 1959.
Clinical Occlusion, April 20 to 24, 1959.
Complete Denture Prosthesis, April 27 to May 1, 1959.
Newer Concepts in Oral Rehabilitation, May 4 to 8, 1959.
Refresher Course in Periodontal Therapy, May 9, 1959.
Advanced Periodontal Therapy, May 11 to 15, 1959.
Complete Denture Seminar, May 14, 1959.
Complete Denture Prosthesis, May 18 to 22, 1959.
The Use of High Speed Instruments and Equipment, May 20 and 21, 1959.
Immediate Root Resection, June 1 to 6, 1959.
Twin Wire Mechanism, June 1 to 5, 1959.

For further information and application, write to Director, Postgraduate Courses, School of Dentistry, University of Pennsylvania, 4001 Spruce St., Philadelphia 4, Pa.

The University of Kansas City, School of Dentistry, announces the following postgraduate courses:

Periodontics, April 1 and 2, 1959.
Cephalometrics, May 6 to 8, 1959.
Oral Surgery, June 19 and 20, 1959.
Materials in Dentistry, Sept. 3 and 4, 1959.
Preventive and Interceptive Orthodontics, Oct. 14 to 16, 1959.
Prosthetics, Nov. 4 to 6, 1959.

For further information and application, write to Postgraduate Division, School of Dentistry, The University of Kansas City, 1108 East 10th St., Kansas City 6, Mo.

The Ohio State University, College of Dentistry, announces the following postgraduate courses:

15th Annual Post College Assembly, April 15 and 16, 1959.
General Anesthesia, April 20 to 24, 1959.
Dental Drugs in Action, May 1 and 2, 1959.
Periodontics, May 4 to 8, 1959.

For further information and application, write to Postgraduate Division, College of Dentistry, The Ohio State University, Columbus 10, Ohio.

The University of Washington, School of Dentistry, announces a new Graduate Program leading to a Master of Science degree. The following courses are available to properly qualified applicants: Fixed Partial Dentures, Operative Dentistry, Oral Pathology, Oral Surgery, Orthodontics, Pedodontics, Periodontics-Endodontics, and Prosthodontics.

For further information and application, write to Dr. Saul Schluger, Director, Graduate Dental Education, University of Washington, School of Dentistry, Seattle 5, Wash.

Temple University School of Dentistry announces the following graduate and postgraduate courses:

Full Denture Prosthesis, April 6 to 11, 1959.
Full Denture Prosthesis—Advanced, April 12 to 18, 1959.
Advanced Surgical Techniques in Periodontal Therapy, April 18 to 22, 1959.
Transographics in Full Mouth Restoration, May 4 to 9, 1959.
Fundamental Periodontics, June 1 to 5, 1959.
Immediate Root Resection, June 1 to 6, 1959.

For further information and application, write to Postgraduate Division, Temple University School of Dentistry, 3223 North Broad St., Philadelphia 40, Pa.

The University of Alabama School of Dentistry will present the following refresher courses:

Partial Denture Prosthesis, April 3 to 5, 1959.

Immediate Root Canal Therapy followed by Apicoectomy, May 7 and 8, 1959.

Pedodontics for the General Practitioner, May 16 and 17, 1959.

Anatomy of the Head and Neck, May 25 to 27, 1959.

For further information and application, write to Director, Refresher Course Program, University of Alabama, School of Dentistry, 1919 Seventh Ave., South, Birmingham, Ala.

Tufts University School of Dental Medicine announces the following postgraduate refresher courses:

Occlusal Adjustment, March 30 to April 1, 1959.

Clinical Adjustment of the Occlusion, April 2 to 4, 1959.

Full Denture Implants, April 6 to 10, 1959.

A Special Participation Course in Periodontology, April 13 to 17, 1959, and Sept. 21 to 25, 1959.

Recent Developments in the Histopathology of Peridontal Disease, April 18 and 19, 1959.

Occluso-Rehabilitation—I, April 20 to 24, 1959.

Oral Roentgenology, April 22, 1959.

Full Denture Prosthesis, June 1 to 5, 1959.

Tenth Annual Berkshire Conference in Oral Pathology and Periodontology at Eastover in Lenox, Mass., June 14 to 18, 1959.

Clinical Dentistry for Children, June 15 and 16, 1959.

Modern Concepts Regarding the Etiology, Diagnosis, and Treatment of Oral Disease, Sept. 21 to 23, 1959.

For further information and application, write to Director of Graduate and Postgraduate Studies, Tufts University School of Dental Medicine, 136 Harrison Ave., Boston, Mass.

Michael Reese Hospital announces that it is now receiving applications for its 12-month dental rotating internships, starting July 1, 1959.

For further information, write to Dental Department, Michael Reese Hospital and Medical Center, 29th St. and Ellis Ave., Chicago 16, Ill.

The Veterans Administration, Medical Teaching Group Hospital, Memphis, Tenn., announces that one rotating dental internship and one residency in Prosthodontics will be available for the year beginning July, 1959.

For further information and application, write to Chief of the Dental Service, Veterans Administration, Medical Teaching Group Hospital, Memphis, Tenn.

The Dental and Oral Surgery Service of the Mount Sinai Hospital in New York City announces that it is accepting applications for internships and residency for the calendar year beginning July, 1959.

For further information and application, write to Dr. Max Fuchs, Assistant Director, The Mount Sinai Hospital, 11 East 100th St., New York 29, N. Y.

The Nomenclature Committee of the Academy of Denture Prosthetics plans to present recommendations for revision of The Glossary of Prosthodontic Terms (J. PROS. DEN. **6:** Appendix, March, 1956) to the Academy this April. For that reason, constructive suggestions are invited. Revisions will involve the addition of terms not included in the original Glossary, deletion of certain obsolete or objectionable terms, and changes in definitions to clarify the meaning of some terms. It is particularly desired that suggestions for new or modified definitions include a proposed definition which is considered to describe clearly the term involved. Any suggestions to be considered must be received by April 1, 1959.

Communications should be addressed to the Chairman of the Nomenclature Committee, Dr. Carl O. Boucher, The Ohio State University, College of Dentistry, Columbus 10, Ohio.

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